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*The Conference Proceedings of the 1998 Air Transport  
Research Group (ATRG) of the WCTR Society,  
Volume 4*

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Volume 4

Editors

Tae H. Oum

Brent D. Bowen

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The Air Transport Research Group of the WCTR Society was formally launched as a special interest group at the 7<sup>th</sup> Triennial WCTR in Sydney, Australia in 1995. Since then, our membership base has expanded rapidly, and now includes over 400 active transportation researchers, policy-makers, industry executives, major corporations and research institutes from 28 countries. It became a tradition that the ATRG would hold an international conference at least once a year. In 1998, the ATRG organized a consecutive stream of 14 aviation sessions at the 8<sup>th</sup> Triennial WCTR Conference (July 12-17: Antwerp). Again, on 19-21 July, 1998, the ATRG Symposium was organized and executed every successfully by Dr. Aisling Reynolds-Feighan of the University College of Dublin. The Aviation Institute at the University of Nebraska at Omaha has published the Proceedings of the 1998 ATRG Dublin Symposium (being co-edited by Dr. Aisling Reynolds-Feighan and Professor Brent Bowen), and the Proceedings of the 1998 WCTR-ATRG Conference (being co-edited by Professors Tae H. Oum and Brent Bowen).

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## ABOUT THE EDITORS

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

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

### *ATRG President's Foreword*

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

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

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

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

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

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# ATRG Triennial World Conference on Transportation Research Antwerp, Belgium July 12-17, 1998

## The Conference

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

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# WCTR '98

Eight World Conference on Transport Research  
Antwerp, Belgium, July 12-17, 1998

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## SMART HUBS :

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*Topic Area:* A3/01 Policy Issues and Transportation Strategies – paper N° 140

*Key words :* intermodality, equity, supply chain management

*Abstract :* The European Union focuses on horizontal integration, including the concepts of interconnection, interoperability and intermodality around which the common policy of transport is articulated.

The clue put forward by the authors is the concept of *vertical integration*, on the basis of the banal remark that freight transport and the logistics sector are services activities and not an end in itself. In the current economy a competitive advantage provided by services often is linked with an value added service. The value added service is added to the basic service provision and precisely makes the difference and thus the benefit. We will present an analysis derived from the OSI model that splits concurrent activities in layers.

Finally we assess the role of nodes in integrated transport services.

**SMART HUBS :**  
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**1. INTRODUCTION**

The European Union focuses on horizontal integration, including the concepts of interconnection, interoperability and intermodality around which the common policy of transport is articulated. The symbolic values of these words either may hide some meaningless or misinterpretation because everyone has his own definition. The private sector has to cope with competition, while the public sector has to arbitrate the action and ensure that the confronted actors will contribute to the general welfare. In this way the performance will be estimated in terms of competitive advantage for the private sector and of general cohesion for the public sector. The latter is trying to make a difficult reconciliation between competitiveness, equity and environment protection (the three E : Efficiency, Equity and Environment). But the whole question is how to act beyond the words ?

This article does not remark the quest for the Graal. It will try to contribute to the endless search of a common transport policy by the Ministers, the Government representatives or the Director General and his services whose missions precisely are to conceive such a policy. WCTR perhaps will provide them some help. The clue put forward by the authors is the concept of *vertical integration*, on the basis of the banal remark that freight transport and the logistics sector are services activities and not an

end in itself. In the current economy a competitive advantage provided by services often is linked with an value added service. The value added service is added to the basic service provision and precisely makes the difference and thus the benefit. The suitable term will be services cluster : transport associated with a series of added services.

Is this idea an evidence of brilliancy ? Certainly not, but it will contribute to enable the decision makers to become aware of some obviousness. One only has to observe the situation in the communication services, in telecommunication, an other interesting field. The V.A.N. Value Added Networks have been a great success and it is virtually certain that information technologies in transport will be the same success. Considering that the so called "*Supply Chain Management*" or "*Customer Supplier Chain*" has been asserted as a theme of seminar or as a subject of contract for consultancy, this bet certainly will be won. Indeed vertical integration, enabling better to satisfy the customer's logic through "customer care", will experience a tremendous development through the information technologies.

That is not enough any more to rack transport actors brains staying in the single field of transport. They have to improve productiveness while being respectful of the environment and good citizens concerned by social progress and regional planning. Indeed, but they also have to satisfy individualised customers, providing them tailor-made services at the price of ready-made services. The transport actor's job is not to carry the trade of his customers but to facilitate the achievement of their task (their "core business") *through the provision of a service enriched with an added value*. That is what modern economy encourages through the development and promotion of contracting out, where suppliers are not subcontractors any more but become real partners. From now on, service providers will have to demonstrate their creativity not only to improve productiveness but also to provide further services.

This paper will illustrate how the *national monopolies centred on the modal infrastructures* and the associated scale economies (technology driven and supply driven) have been destabilised by new technological alternatives and by the single market. The monopolies were of course prevented from providing value added services because they would have been accused of unfair competition by the private companies whose business was limited to the area left free by the monopolies. But the differentiation progressively imposed by the suppression of all kinds of protection and the generalized competition *was to make the companies focus their strategy on the competitive advantage*. The shipper who is concentrated on his domain of excellence requires the supplier to do the same and to provide an additional service relative to the basic one so that he will also contribute to the competitive advantage.

Thus today the situation has totally changed - *there is no monopoly left and derived products are not prohibited any more*. The service provider now is appealed to provide a plus, which obliges him to work beyond his basic occupation and to follow the logic of the customer. It is the demand and not the offer (demand led) which will segment the market. The result of the chronic over-capacity will be that the basic product will not allow to survive any more unless one rules the market. In the opposite case, which will be the general case, what will allow to survive will be creativity and value added services. Thus the conditions in which a new generation of transport



and/or logistics operators will be able to introduce added value into the system should be studied in detail. We will see that the privileged places to introduce added value are the nodes of the network which both will contribute to the horizontal integration desired by the public authorities and to the vertical integration essential to the operators survival.

The nodes of the freight transport system both are sources and wells. Wells because they *allow to adjust the global products to the local markets* and sources because they contribute to *the creation of new products* through local economies, favourable to trust relationships, propitious to innovation, and opening the global market to these products. Thus the global economy will not be a no-culture economy which erases local identities, but an opportunity of cross enrichment, pushing further the limits of the international division of labour. In that way transport recovers its real role which is not to develop rail or road, air-fleet or merchant navy, but to open market areas and to develop economic and social exchanges.

## 1 - THE RECENT ECONOMIC DEVELOPMENT IN THE SECTOR OF TRANSPORT

### 1.1 - From scale economy and technical monopoly...

On the one hand, the significance and long life duration of the infrastructure investments and on the other hand the concern of public authorities to make the largest number of people benefit from a minimum service without exclusion by money, have led to railways nationalisation in Europe and to *public service duties for the non-profitable services*. Indeed, the community did not want to deprive the users who could neither behave as customers nor pay a price which would cover the costs. It was thus the community who had to ensure the required funding.

Scale economies or increasing efficiency were put forward to justify a higher patronage than the patronage allowed by the market, *the marginal cost being lower than the average cost*. Many studies have tried to check the validity of these statements according to the type of traffic concerned. These works are quite severe and not very conclusive because the costs and price development mechanisms should be known in detail as regards linked services and multiple tasks : travellers and freight, more or less rapid trains, longer or smaller distances, and batch sizes ranging from parcels to complete trains and boxes.

Without reviewing these works, what can be stated is that *demand differentiation*, a characteristic of the modern economy, is *in opposition to scale economies*, obvious for homogeneous traffic corresponding to a single service. In the former Soviet Union railways were operated as urban subways, with the same schedule - speed and stations - and with the single constraint of safety headway. Then the costs by traffic unit (passengers x km or tons x km) were unbreakable. If demand diversifies and alternative solutions are offered to the customers to satisfy tailor-made services, the technical monopolies *disappear through the separation of the profitable traffic and the wast-*

*ing of the scale economies.* It is true whether there is deregulation or not. Only the market will enable companies to solve the problems raised by the growing complexity of modern economies.

## 1.2 - ... to the value added services

An operator having the advantage of a monopoly situation will be prevented from providing additional services because these services are not included in his specifications. Then a private activity will be implemented, *at the boundaries of the monopoly* in order to complete the offered services. The operators working at the limit of the domain covered by the post services are known. It is the same for all of the public services including electricity, telecommunications, railways which have created a parallel activity owned by private companies, often hardly profitable. Of course they were very jealous of any infringement from the public big brother who they depended on. Indeed the public companies were able to kill them through prices, confiscating any potential profit, or through unfair competition. It was the same for the combined transport operators.

The above remarks demonstrate that the shift from a monopoly situation to a complete opening to competition only is not possible in part because of the considerable risk of a progressive decrease of the profitability of the monopoly remainders, especially if they have to keep within the basic services (core business) excluding any value added service, reserved for the peripheral companies of the competitive field. The technological alternatives will change the monopoly into diminishing asset and the upper outflows, that is, the additional services will remain prohibited. When competition cannot be avoided any more, the basic service is paid at a price hardly covering the costs unless the company has a prevailing market share, which competition will make more and more uncertain. The competitive advantage thus will be obtained through additional services and any company prevented from any action on this field is doomed to failure. Now, to be empowered to provide additional services the condition is to renounce the monopoly.

What could be observed in telecommunications certainly will happen in transport. There is no intermediate condition and better to take a place on the competitive field than to call for a narrow monopoly which will prevent from any potential development of business (as a ban to chase on a land well stocked with game). But to do so, *what has to be changed is the behaviour of the field people* who were not allowed to deal with such services. They don't know the services very well and they will be faced with competitors they did not usually cope with. The formerly dependent sub-contractor now has become a real actor and the national railway company will have to get used to the fact that former dependent customers are becoming rail operators. In return, the previous monopolistic operator will be allowed to provide additional services, complying with the customers logic where the services are not limited to transport only.

## 2 - CHANGES OF PROSPECTS

### 2.1 - Transport policy or the stakes of horizontal integration

The 3 E concern : Efficiency, Equity and Environment and the 3 inter : interoperability, interconnection and intermodality. These political considerations especially concern the public authorities who desire to contribute to economy competitiveness preserving the values of solidarity and environment protection. Moreover the Transport Ministers and DG7 also have the legitimate care for taking into account the respective interests of the transport actors. From which *an angle in favour of horizontal integration*, which remains in the field of this ministerial department skills.

This approach relies on an unavoidable division of the responsibilities between transport and its socio-economic environment. However the drawback of this approach is to underline the *internal problems of transport* more than the *objectives of transport*, an activity of service which is to be assessed in terms of impact on the whole social and economic activity. Indeed transport modes both competitive and complementary should cohabit with one another and the infrastructure needs should be satisfied. But the addition of the modal demands results in an unrealistic whole. Moreover there are more and more problems as regard the insertion and funding of these infrastructures. Now transport is not an end in itself and the important thing is to contribute to the development of Europe, of its economy and welfare.

Thus transport questions cannot be addressed any more from the inside of this activity field while the provided service is evaluated on the basis of its impact on the general economic and social activity. It's more and more difficult to keep within the limits of the single *horizontal integration*, inside the transport sector, *being unaware of the vertical integration*, the so called transport logistics in the customer-supplier chain (the "Supply Chain Management"). Now the transport market segmentation, as it replaces the offer by mode, more and more lends itself to this vertical integration. The differentiation of the customers (the "personal care") is made for "demand led" transport and not any more for "technology driven" transport.

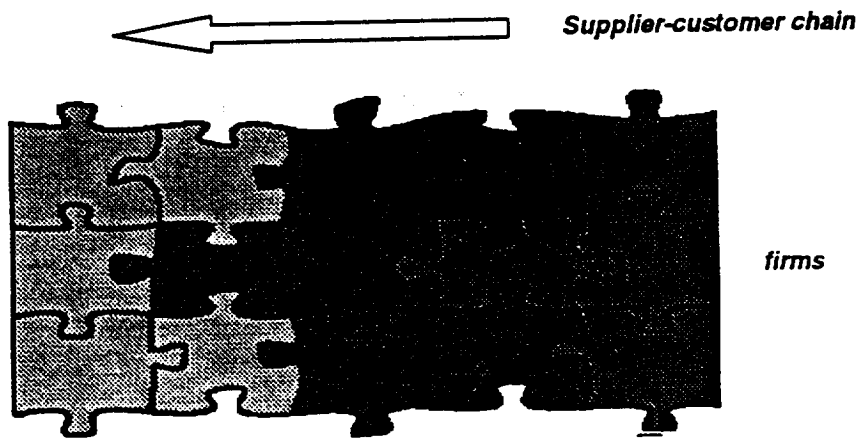
### 2.2 - The recent significance of additional services

The reason why the concept of value added services has rapidly prevailed in telecommunications is that information technologies have given a tremendous boost to the additional services which, added to the main service, are making the difference. These additional services provide a plus relative to competitors (*competitive advantage*) and have a lever effect on the market shares. A perfect competition hardly allows to earn money from the basic service because the offer is superabundant and unless to benefit from a prevailing situation, which will become very difficult, the scale economies become inaccessible and the "economy of scope" is the only one to be accessible.

The customers-suppliers chain is not any more a succession of rings which, once joined would make a single channel carrying the raw material to the final product with from upstream to downstream the logistics of supplies, production and delivery. In fact this chain is *made of overlapped sub-sets*, where every supplier doesn't practice the others' occupation but contributes to the final integration through interpenetrating.

Then it is possible to combine components on shelves to result in a product-service set, suitable for any individual situation and for the best satisfaction of the final customer. The combination of customised kits becomes possible in real time thanks to the information system (IS) which synchronises a continuous process from the parameterised order to result in customised deliveries at low price.

To take a familiar example of road engineers, the breakthrough of the GSM combined with GPS (cellular phone plus positioning system) makes it possible to provide efficient rescue services (accident and/or repairs) which formerly were under the responsibility of the emergency call network. Other services come to be added such as road guidance and the comfort information regarding tourist services. The combination of the automatic warning sensors, of the short message services (SMS) on the available channels, and of the traditional vocal messages make this *services cluster accessible* without degrading the priority services. Thus it is possible to take on the watering of plants and the food of pets if there is nobody at home while the occupant is at the hospital. The identity record of the customer available at the call center equipped with the appropriate data bases allows the service provider to take on these selected additional services.



### 2.3 - The customers-suppliers chain or the stakes of vertical integration

The insertion of transport in the logistic chain is not new. When a parcel delivery company carries clothes on coat hangers to the stores, avoiding to put them into cardboard and to iron them, it did so. It was the same when suitable goodies were provided during the trip in order to avoid the stress of the animals which could result in a loss of weight. The service provider complied with the logic of the customer in order to improve his offer without becoming neither a clothing manufacturer nor a veterinary able to take care of animals.

The global economy, the single market and the information technologies will give an other dimension to this interpenetration, the vertical integration. The company, a customer of transport, will focus on its basic product (its "core business") and externalise everything the others can do better. This is possible only if there is no cut of information transmission from the final customer up to the producer and his suppliers. It requires a transmission of information without mistakes nor gaps and thus without

multiple data capture and immediately assimilated into the information system of the company. What is referred to are the bar code and other electronic tags, the other automatic reading means and the coded messages such as EDI.

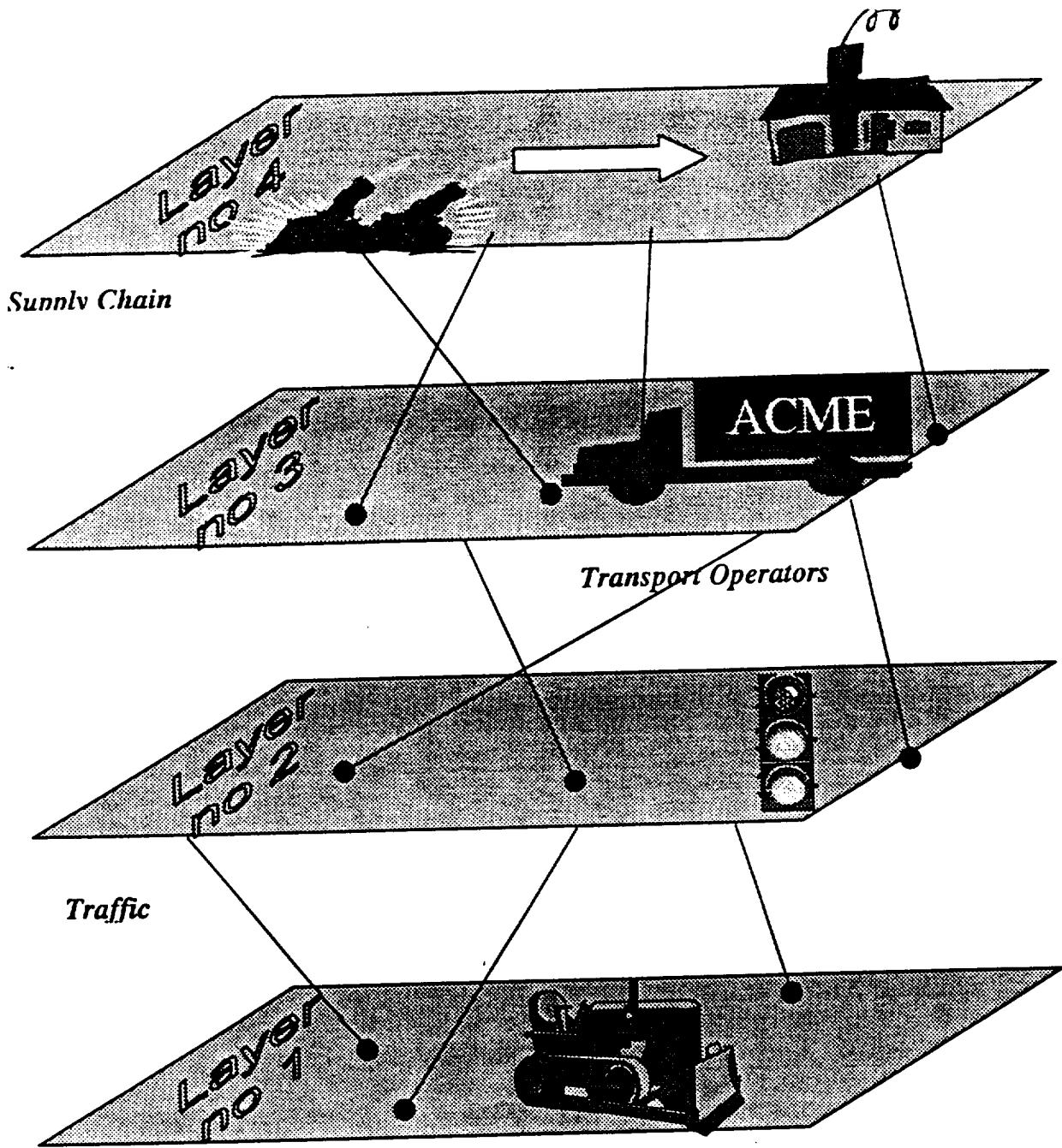
All of the nodes of the production system will have to contribute to a competitive advantage and to a plus which will make the difference. We will address the nodes of the "web" and not any more of tube ends because the customer-supplier chain is not linear any more with a leader company and dependent sub-contractors. The chain now is a web where a supplier has several customers and a customer has several suppliers. The intelligence thus will be assigned on the nodes of the network and creativeness, the plus of the winner, will not be the basic service any more but its valorisation from the viewpoint of the final customer. It is vertical integration.

The tour operator who provides the customers will be able to negotiate for instance a global winter sport service including, ski lift, ski lessons and equipment rent, making the steps easier at the arrival at a price lower than the one obtained by the single individual. The manufacturer of plastic for car dashboards will create a joint company with the suppliers of measurement devices and will deliver a complete sub-set which will fit the car as a Lego piece with the minimum of operations for the required connections. It will even be difficult to distinguish between the equipment manufacturer and the designer because each of them will produce a system with associated services.

### 3 - FUNCTIONAL ANALYSIS OF THE CHANGES IN THE LOGISTIC CHAIN

#### 3.1 - The OSI layers : from the infrastructures to the organisations

For a better analysis of the development of the relationships between the various actors of transport, it could be interesting to formalise all of the situations, using a model. It is a natural approach in science but it may be reducing as a representation of the phenomenon if the extent of the modelling logic is too large. What is dealt with is a model of transport practice and customers relationships which will be represented in successive layers, from the most simple to the most complex as regards the role of the actors.



*Transport Infrastructures*

This has been based on a large scale similar work achieved at the end of the seventies in the sector of telecommunications. Data transmissions were developing and the international organisations of standardisation (ISO, IEC) were interested in the domain and launched several working groups gathered around the acronym OSI, Open System Interconnection. The first work consisted of the design of a **general model of the elements intervening in the complex chain** of data communications so that many experts groups could operate in a consistent way in the upstream determined frame. This model by OSI describes the domain in terms of a series of elements and services layers, the analysis principle of which consists of the hypothesis that every layers only knows and communicates with its direct former and following layers. It is the updat-

ing of the mathematicians proven principle : "when the problem is too complex let's first separate the variables".

Applied to transport, the method allows to derive four layers :

*The first one* concerns the infrastructures considered as a physical investment included in geography and depending on civil engineering. It can be considered as a passive layer, a little like sleeping Beauty, whose activation depends on a charming prince who will give her the value she deserves.

*The second layers* will involve the vehicles put on the infrastructure which implies to take traffic into account. It is the job of movement or traffic engineers who see to it that infrastructure physical capacity will be used for the best. Efficiency first is evaluated in terms of safety and capacity but this level does not imply any commercial relation with the transport customer. The matter is infrastructure operation and not commercial operators tasks.

*The third layers* is related to commercial action. The matter is to satisfy a demand the operator will reply to with an offer determined in terms of his service level and involving organisational choices as regards the nature of the vehicles and load, the routes, the transit through platforms or hubs, the connections etc.. The offer-demand equilibrium will be obtained through tariffs. Here what is considered is only transport service, which implies that if there is pluri-modal service, horizontal integration only will be dealt with.

*The fourth layers* concerns vertical integration, which situates transport services in the customer-supplier chain and thus takes into account the customer's logistics through the provision of the additional service which facilitates the desired externalization of what he does not consider as his basic occupation. The logistics service provider will take the opportunity of the freight transit or of the tour operator's trust to provide him a kit, a global service including transport and tourist services, freight transport and customer care. In the modern world service is linked with product and product is linked with service. There is no more clear cut between the service provider and the industrialist but both roles are interdependent, each of them keeping his basic occupation but making a step towards the other. €

### 3.2 - Global analysis of the organisation

In order to analyse the mechanisms involved it is interesting to refine the analysis. This should start noticing that at the time of OSI model design a very small number of actors totally prevailed in the telematics sector : IBM represented 70 % of the computers market, and the telephone operators were managing a very opaque monopoly. Since then *many intermediary specialisation* have been created for the great benefit of the final customer. From the economic sector systemic analysis viewpoint, the model proved very useful to position the new products, while it was not very efficient in standard design which was its initial goal. In particular the developers of values to add to the simple data transport had a clear conceptual frame allowing them to intervene despite the rapid development of the technico-economical landscape.

The transport sector has developed in a similar way. The monopolies have known a progressive decline while *new services and new operators have emerged*. If the resulting general scene may look complex, what can help to understand is to observe that in general each actor in the logistics chain only had to know his direct customers and suppliers.

The logic of this analysis is close to the functional analysis which tries to distort a complex system into simple units defined by their functions without detailed description of each part. The other characteristic is the stress put on *exchanges between units* according to processes included in what is called interfaces.

Today for each transport function there are specific computer functions which are summed up in a further column. These functions linked with information new technologies will be analysed in the next paragraph.

A potential illustration :

Transport, Layers		Information System Support			
...					
4	Supply Chain Management	Global Operator (ex : Global One, SITA)			
3	Transport Corporations Sea Carriers Air Carriers Trucking Co...	<i>Specific Software:</i> EDI, E-mail et E-form, Planning & reservation Software			
			2	Mobile Means & Mobile Equipment	Real Time Traffic Control
			1	Transport Infrastructures	Information & Communication Infrastructures

Clients des services transport

What is to be noticed is that as long as the monopoly situation was lasting in transport, the question of the real function of each actor and thus the layers analysis was not to be addressed. The relations in the transport chain were stereotyped, fixed by old and constraining rules. To give an evidence of *the formal character of these rules and relations*, it's enough to recall that they minimised the position of the final customer and left out the essential factor of quality. Only an analysis determined by the position in the service layers (in the chain) can allow to understand the factor of qual-



ity. In the same way this method (or model) allows to give the real situation of the customer as intermediary or final one.

Figure 4 clearly is arbitrary. However it corresponds to the functions and occupations known in transport. The progress from the bottom to the top corresponds to *a transition of the occupations* as it is observed in firms :

**MATERIAL ↔ TECHNIQUE ↔ MARKETING ↔ ORGANISATION**

This model reveals a functional specialisation in the chain, which is considerably reinforced by modern economy tendencies. *Within two decades the relative strong position of the actors imperceptibly has proceeded from level 2 to level 4.* The deregulation and over-capacity of infrastructures and equipment has given the power to the final customer by means of the global operators.

Another reason for this move of strength also lies in the growing significance of the information systems and technologies which help to manage moving objects. At the current stage of technology, *electronic data interchange (EDI)* is far from being generalised especially in small and mean companies. It is not even efficient for small quantities. The great force of the international freight companies lies in their *global data communication networks* ensuring a rapid and reliable communication with all of the functional levels, creating shorter information channels. The traditional organisation also required successive exchanges from level to level slowing down the process and increasing the sources of mistakes. The crucial advantage of these rapid channels for information traffic lies in the availability of servers implemented by the companies on their networks. The tracing/tracking functions automatically are ensured. They are essential quality elements in freight transport operations : not to loose objects and/or to find them again quickly.

It also should be noticed that the functional layers correspond quite well with labour division as it is known in this economic sector. On the opposite the upper layers can be subdivided to take into account the refinement of transport functions through the emergence of new services. Especially the final customer may want *to externalise the logistics function in a very large extent.* To be strict, an equivalent scheme should be added at the top of our diagram for the functions of the company.

This representation in layers only is a first approximation. The *acceleration of the production cycles* requires higher performance organisations than the one based on the simple sequential transmission of products and information. Once again a model allows to clarify the concepts and mechanisms involved to obtain the expected performances.

### 3.3 - Transport integration tools

Again, we will rely on *the traditional data transmission models* and transfer them to transport. It is useful because the computer science sector has made many efforts to represent complex processes and it's legitimate to benefit from this progress. Of course they should be used with caution because analogies may be deceptive and information to convey is not a parcel to delivery. However the *central concept in effect*

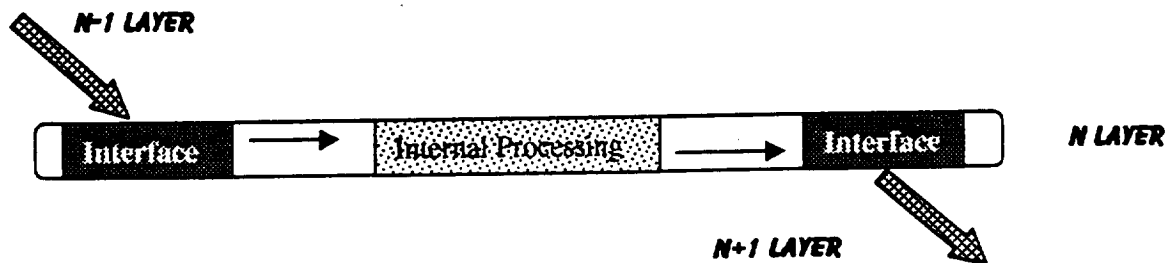
of computer science today is the **object** (object-oriented model/programming). As one can see, analogies are working with benefit in all directions !

Four little models are going to be used in order to clarify the methods contributing to the integration of the logistic chain :

Concepts	Tools
Interface Formalisation	Automatic identification, E forms, EDI
Exchanges acceleration	Channels shortening
Demand anticipation	Booking (servers)
Product cycle forecast	Data Warehouse (Data Bases)

### Formalisation of the interfaces

The question is to clarify the *exchange process* at the level of the layers (function) in the strict sense of the term. It means to analyse the interfaces between two layers (functions) so that the process can run in an integrated way. In the instance of a maritime terminal with containers, lorries and boats should be processed while the layers process would lie in the management of the containers inside the terminal itself.

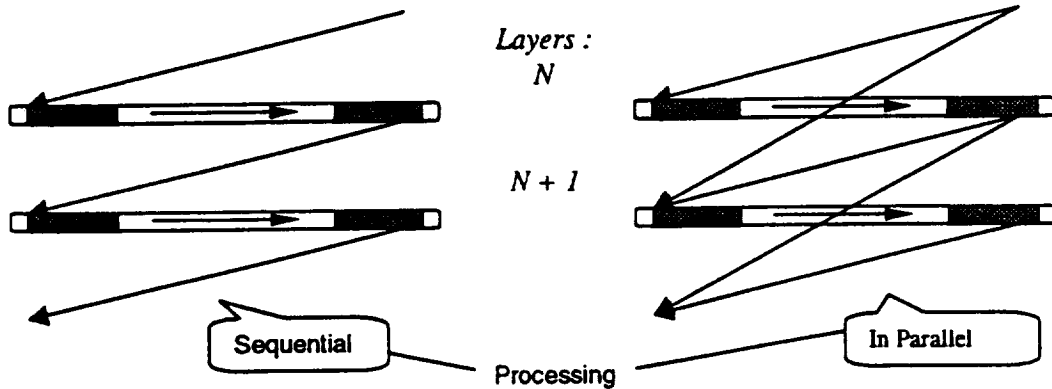


This representation puts forward *the interface as a crucial point* in services integration. At this point of junction between two companies, two services or two facilities all of the precautions have to be taken in order to avoid that potential disorders will propagate from one entity to the other. Either in a purchase service or at the door of a terminal, the administrative procedures allowing to isolate entities often are long and constraining. The first condition of processes integration is to reduce the interfaces without loss of rigour. This result progressively has been obtained using *software in the interfaces which contain clear operation orders*. For instance electronic forms are proposed by a firm to their partners. The software which manages the form ensures a determined level of quality in the information transmitted and received. In the same way the *automatic identification (AI) systems* are very useful in the field of logistics

to reduce the delays at the interfaces through the transmission of the moving objects identity with a great reliability.

### *Acceleration of exchanges*

The layers model has demonstrated that freight is subject to many processing steps. As long as the steps proceed according to strict sequences, the delays of each step accumulate mechanically. The acceleration technique consists in launching two or more operations in parallel.



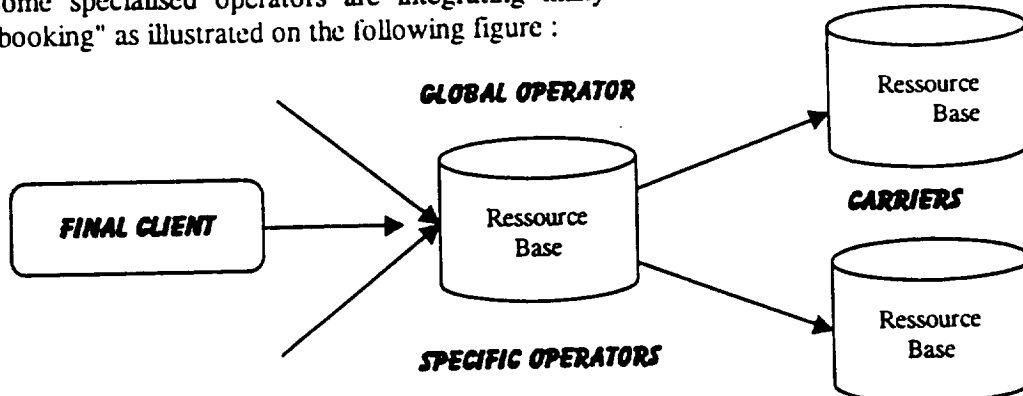
Indeed one may think that this technique only concerns the information flows linked with transport. Indeed it often provides a significant performance benefit insofar as it ensures *an integration of the processes on two levels at least* as illustrated on figure 4. Two parallel physical processes are launched which will be synchronised at the last moment.

A typical example concerns customs clearance which can be achieved before the arrival of the freight at the port by means of an electronic customs declaration at the time of departure from the previous call. At the same time an electronic mail sent to the arrival terminal allows to prepare the warehousing of the containers to come. More generally a global operator may *launch several operations in parallel* through his direct participation to several transport functions. It is interesting to observe that a classical model of information technologies (*parallelism*) also can be applied to the logistics chain.

### *Demand anticipation*

In transport, movements are made using consolidation/deconsolidation techniques ensuring a suitable use of the resources (wagons, lorries, ...) as a result of the significance of the transport means turnaround frequency and of the small shipments volume. As a result of the statistical law of great numbers, the means are correctly used without particular efforts. On the contrary the situation changes on long distances where freight, often containerised, moves using much larger unit capacities but in a

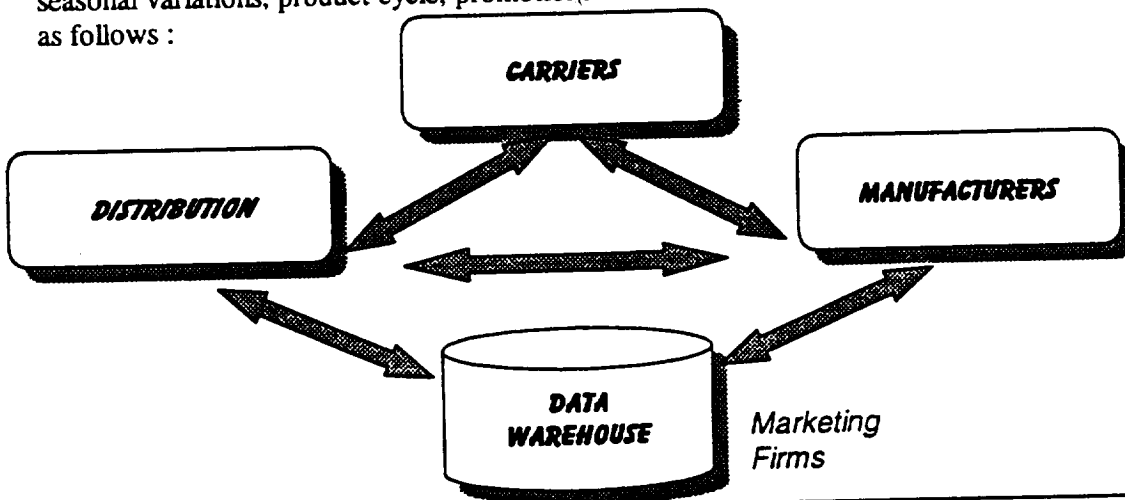
more limited number - planes and boats -. For the latter a booking has to be made in advance for the passing towards a determined service. It is a critical phase : a booking made too soon may be inaccurate, too late it may miss the passing at the boat call. Some specialised operators are integrating many demands to make an efficient "booking" as illustrated on the following figure :



On the basis of the integration of the demands of his various customers, the specialised agent can speculate at short term through anticipated firm bookings. Aggregating many potential demands the logistic operator can lock up firm bookings of means. It is the well known model of the client/server which is applied in this case. Then *sparse demands can be organised as pairs on a server*. There even can be servers of specialised means and/or functions independently of any real capacity. A NVOCC operator just organises pairs of demands for means he does not manage. The transitivity of the phenomenon also should be observed : the success of this information technology reinforces in a large extent the practice of the same model in transport.

**Long term forecasts**

The closer and closer integration of the large retailers and manufacturers enables them to exchange operation information in order to integrate better their own units. Considerable computer networks directly connect the *point of sales terminals (POS)* to *marketing data warehouses* in addition to their strict operational role in triggering new supplies. The information about the effective sales of the products by locations, periods, categories of persons, etc, are sorted, dispatched, aggregated using the most recent computer techniques. Properly collected, sorted, analysed this information allows to make long term forecasts to take into account sales fluctuations caused by seasonal variations, product cycle, promotions etc. Thus the flows can be represented as follows :



These techniques recently have developed in a great extent with the development of specialised software called "data mining". The effect on transport chain can appear as a low effect. On the contrary, the skilled logistics operator will use these means to optimise his transport and storage means on the basis of relevant and updated information thanks to a continual feedback.

## 4 - THE CONSEQUENCES ON THE ROLE OF THE NODES

### 4.1 - Nodes and horizontal integration

Several meanings of the term "node" can be used to qualify the more or less suitable management of a transport system. To remain simple, we will address the crossing of several communication lanes which are locating the critical transport places, and *more precisely the points of enforcement of the public policies and firms strategies*. It is easy to demonstrate that the nodes of the network are the privileged points of enforcement of the three "inter" (interoperability, intermodality, interconnection), or of the three E (efficiency, equity, environment) of the public policy. The following paragraph also will show that the nodes are the privileged intervention centres of the private strategies of vertical integration.

*As regards the three inter :*

- Interoperability refers the standards, weights and sizes, currents, track gauge, and loading gauge. The transparency at borders comes to cancel the unuseful or incidental nodes. The action of the public authorities is to make compatible and if possible homogeneous the characteristics of the components of the transport system used and consequently the systems for all of the transport modes.

- *Intermodality* stresses the transfer points. They not only will have to provide the means for handling and transfer allowing the shift from one mode to the other but also the commercial facilities and the transparency of information.

- *Interconnection* aims at linking the three<sup>4</sup> geographic levels from the local to the national, continental and global ones.

*As regards the three E :*

- *Efficiency* implies to use the nodes as cores. The term hubs is used to describe organisations promoting the efficient use of infrastructures thanks to connections, shuttle services, consolidation - deconsolidation for parcel deliveries, to *random demand consolidation* to use large carriers and complete loads through the consolidation of diffuse traffic.

- *Equity* comes to assign equitably the accessibility on the territory taken into account, in order to check that the service conditions don't result in any exclusion and that the

"right to transport" in bearable economic conditions is satisfied. The economic exclusion mainly is coped with by the tariff policy but the taking into account of the geographic exclusion is based on well managed interconnection and intermodality.

- *Environment* implies that the mode of transport used should be the least aggressive as possible for environment and this requires load breaking at appropriate nodes to shift from a generally more polluting local transport to less polluting long distance transports.

#### 4.2 - Nodes and vertical integration

The significance of vertical integration generally is under-estimated for the three following reasons. It depends on the firms strategy and not on the public initiative and thus it does not concern the transport domain only. It is based on a marketing approach which is very mobile and thus difficult to observe. It was considerably facilitated by information technologies and by a market segmented by demand and not by offer any more which explains that its full development is recent.

- The strategy of the firms in an extended competition situation is based on a re-centring on the basic occupation - "core business" - on the externalisation of what can be achieved by others in a more efficient way, and on a better repartition of intelligence changing the sub-contractors into less dependent partners, becoming multi-customers and creating values through all kinds of innovation. The chain of value changes in depth. It is not linear any more but looks like a variable geometric web where the technical links trying to optimise the whole and the marketing links involving a better equilibrium of the strength relations are interacting all the time. The result is network firms the development of which totally depends on information technologies and electronic business called "B to B" (Business to Business). The transport part of these modern activity networks is called Supply Chain Management. We prefer the expression Supply Web Management. In this new economic frame, the emergence of logistics service providers is a major phenomenon which is going to overturn transport because it results in the arrival of new actors who are playing a more and more prevailing role.

- *The marketing approach* taken into account in our analysis does not include the shippers. It would go beyond the frame of our study. However what should be observed is that these customer firms will make less and less direct transport but will apply to logistics services providers who will provide extended services. This is true for the private individuals who will apply to tour operators for their leisure. The logistics providers will be kinds of wholesale traders who will purchase wholesale transport to resell retail transport with value added services. In USA the member companies of the "Intermodal Marketing Companies" association are experiencing a huge development. Of course these companies must accept a commercial risk to be able to resell the capacities purchased to the carriers which implies *reliable and attractive relationships* with one's own customers. These relationships will be developed through the value added services.

- *A segmented market and an information feedback from the final customer to the supplier* are the two prerequisites to weave a suitable customer-supplier web and

make the best use of the available means especially transport infrastructure. The number of services linked with transport may be infinite because what matters is the activity program satisfying the final customer and not the division into occupations. If information is not partitioned among the technical actors, it allows to integrate all that can be scheduled on the basis of *the final demand characteristics*. Among the most practised services the usual logistics services will be mentioned : handling and storage, stocks management, packaging including labelling, orders preparation, back office including invoicing. Moreover the achievement of sub-sets will change the logistics provider into an assembling operator as an industrial to adjust the global product to the local market on his platform close to the final customer.

### 4.3 - Intelligent platforms or "smart hubs"

Now it is possible to clarify the four layers characterising the organisation of the modern transport system used by the socio-economic activity. It is possible to demonstrate that smart hubs will be one of the main means to conciliate *public policies and firms strategies*. The analysis of the present situation only will be relevant if the characteristics of modern economy are kept in mind : a global market, differentiated products-services resulting from the activity of firms connected by a virtual network of *partnership links in constant development*.

The system runs on the basis of an infrastructure network including efficient connected nodes ensuring efficient exchanges between modes and playing the role of sources and wells to provide vehicles and equipment at the appropriate rate (containers, trailers, pallets etc.). These means will be operated by commercial actors operating on a *market of services* with a prevailing socio-economic objective. The information system regulating the system can be located anywhere because it is intangible. However the suitable running of this system requires that these platforms are transparent and send messages allowing tracing and tracking. Transport operators will have to schedule the vehicles moves from the ports, airports, railway stations, combined transport depots, parcel delivery wharf and hubs of all kinds. As for the logistics providers they will have the best position to integrate transport in the customers-suppliers web. They will act at privileged places perfectly connected to the transport system nodes or located at the same terminals.

The only way to offer global and adjusted services on a market without geographical limits using local synergies based on trust relationships is to use communication and information new technologies. Without data warehouses and remote processing, the webs, bases of the modern competitive economy would be impossible to manage. The so called integrated logistics is based on a services cluster. In this cluster, the transport service indeed plays a major role but it is not the only one to determine the customer's choice. Thus the operator must improve the way he satisfies the needs of the final customer and public authorities must give the best position and dimension to the nodes in terms of the 3 E. Moreover they have to tariff the use of the infrastructures so that *Efficiency will coincide with environment protection and the required consistency of Europe, indispensable for equity*.

### 4.4 - A new deal linked with the emergence of E-commerce

E-commerce or electronic business includes two domains : "B to B" (Business), the basis of the partnership between firms and "B to C" (Customer) from the firm to the private individual. Electronic business goes beyond the simple transaction (in the meaning "il est d'un commerce agréable" ) and includes all of the electronic exchanges between firms including the catalogues and technical data (including plans) useful to simultaneous engineering and after-sales service. E-commerce includes E-mail - electronic messages - a non structured mail, and structured data exchanges such as EDI and semi-structured exchanges including graphs and plans.

Among the products of the productive association between computers and telephone, the net will be included. The call centers also have to be mentioned. There an operator can connect a correspondent with another interlocutor or with another centre using the data available on his display, launched by the phone number and giving all useful information. E-commerce potential is so great that all of the economy will be affected together with transport. Dell had the opportunity to rank third in micro-computer sales thanks to direct sales and Internet. To understand this tendency the *intangible services* and products sales have to be distinguished even if these products include the associated services.

The sale of services does not require deliveries in the meaning attributed to this term by carriers, and thus it will develop without transport prerequisite. The field of transport includes intangible elements such as *banks, insurance, travel and tourism*. The staggering emergence of E-commerce is dramatic even if many are not aware of it. In France, the firm which has the highest turnover through E-commerce is a travel agency. In the United States a city from the Middle West suffers from job shortcomings since it has become the world capital for bookings of all kinds.

However as regards products including a material support the scene changes because it is not enough to order, deliveries are required and *the level of service of the deliveries commands the development of E-commerce*. The direct sales companies were obliged to demand help because they could not ensure the deliveries at the suitable level as a result of the unreliable character of the delivery services. Indeed one can ask for pizzas delivery but a book at a virtual bookseller will be too expensive or delivered within uncertain delays. Without organised local delivery points, as in Japan, one risks to loose one day at home waiting for a delivery man unable to precise his time of arrival assuming he respects the forecasted day. Everyone to appreciate the delights of E-commerce !

The development constraints of E-Commerce "B to C" illustrate the significance of vertical integration and of the satisfaction of the final customer. It's certainly the first time in the civil logistics background that not only the logisticians but their customers report the significance of logistics. Thus there is a shift from the corporatism of self-positioning towards the management, to a strong demand to put logistics at a strategic level. In other words transport is now considered in terms of vertical integration relative to the final product and not any more in terms of horizontal integration only.



## 5 - CONCLUSION

The above considerations can be summed up recalling that public policies cannot be unaware that the duty of any contractor is to satisfy the final customer. To do so a double integration is required, that is horizontal integration indeed, a characteristic of transport, but also vertical integration, "the Supply Web Management" inserting transport in the social and economic activity. The nodes of the network will be the privileged enforcement points of this double integration and information technologies will boost the value added networks. It is essential to take these facts into account to assess the projects depending on the completion of the trans-european network (TEN) recommended by Title XII in the Maastricht treaty.

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**The Link between Total Factor Productivity, Prices and  
and Financial Performance: Applications to  
Air and Rail Transportation**

by

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## 1. INTRODUCTION <sup>1</sup>

Total factor productivity (TFP) has been a principal means of measuring performance both for monitoring performance improvement over time as well as performance comparisons across firms. Productivity compares output quantities with quantities of inputs (more specifically, the growth in outputs relative to the growth in inputs). However, strong productivity performance is not necessarily an indicator of strong financial performance; and the converse is true as well, for example, firms with market power can achieve profitability despite poor productivity performance.

There is reason to expect some correlation between productivity and financial performance, but the relationship is not exact. Stated simply, productivity compares *quantities* of outputs relative to *quantities* of inputs. Financial performance depends on the *revenues* from outputs compared to the *expenditures* on inputs. A firm can be very efficient in terms of outputs per input, but it could be highly unprofitable if the revenues received are low compared to what it pays for inputs. Conversely, a firm with market power might be inefficient in input use but compensate financially by changing high prices. Nonetheless, it is possible to establish a direct link between productivity changes and financial performance. This is shown in part 2.

## 2. PRODUCTIVITY, PRICES AND FINANCIAL PERFORMANCE

Productivity compares outputs with inputs, more specifically, the change in outputs compared with the change in inputs. One can compare one or more output categories with one or more input categories. However, such partial measures of productivity, although popular, are often misleading because they do not take into account other changes in outputs and inputs. For this reason economists advocate comprehensive productivity measures, called multi-factor productivity (MNP) or total factor productivity (TFP). The index number approach to TFP measurement compares the growth rate of a quantity index of all outputs with the growth rate of an input quantity index.<sup>2</sup>

As noted in the introduction, productivity and financial performance do not necessarily move together. However, they are linked by examining changes in prices received for outputs and prices paid for inputs along with the productivity changes. To illustrate the links, use some simple algebra for two time periods, 0 and 1. One can think of a single product firm employing only one input, or

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<sup>1</sup> Material for this paper is drawn from papers with various co-authors listed in the references: Waters and Tretheway (1997); Waters and Street (1997); and Waters, Oum and Yu (1997).

<sup>2</sup> An alternative approach to TFP measurement is to measure the shift in an econometric production or cost function. The interpretation of TFP is not identical in the two approaches (see Oum, Tretheway and Waters, 1992, for an explanation, or Diewert, 1992 for a more rigorous exposition). Because we wish to make comparisons of prices with quantity changes, it is appropriate to use the index number approach to TFP measurement.

index numbers to represent multiple output and input prices and quantities. Note that for index numbers, the respective price and quantity indices must be dual to one another so that there is computational consistency.<sup>3</sup>

$P_0$  and  $P_1$  are output prices (indexes);

$Y_0$  and  $Y_1$  are output quantities (indexes);

$W_0$  and  $W_1$  are input price indexes;

$X_0$  and  $X_1$  are input quantity indexes;

hence

$$R \text{ revenue} = P \times Y$$

$$C \text{ costs} = W \times X$$

Costs include capital costs, i.e., these are total economic costs.

$\pi_0$  and  $\pi_1$  are measure of economic profit; for analytical convenience defined as the ratio of revenues to costs rather than the difference.

$$\pi_0 = R_0 / C_0$$

Note that there is no requirement that economic profits be zero.

Total factor productivity (TFP) is measured by the growth of output relative to the growth in inputs:<sup>4</sup>

$$TFP = \frac{Y_1/Y_0}{X_1/X_0} \text{ or } \frac{Y_1/X_1}{Y_0/X_0} \quad (1)$$

(The second expression is the ratio of a TFP index for each period).

It is desirable to link productivity measurement with financial performance. This is straight-forward,

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<sup>3</sup> The price and quantity indices must satisfy the "product test," i.e., the ratio of price indices over two periods times the ratio of quantity indices should equal the ratio of corresponding expenditure indices.

<sup>4</sup> For simplicity, the index is written in simple ratio form. For calculations we use the Tornqvist or translog form of an index number, which would take the natural log of outputs or inputs for respective years, weighted by the average of the respective revenue or cost shares.

but note that because TFP data includes capital inputs and their service price in calculating productivity; it is economic and not accounting profits which are to be compared with TFP. As noted, for analytical convenience, we work with economic profit  $\pi$  as a ratio of revenues to costs rather than the difference.

Any change in profitability between the periods is indicated by the change in revenue/cost ratios:

$$\pi_1/\pi_0 = \frac{R_1/C_1}{R_0/C_0} \text{ or } \frac{P_1 Y_1 / W_1 X_1}{P_0 Y_0 / W_0 X_0} \quad (2)$$

which is rewritten:

$$\pi_1/\pi_0 = \underbrace{\frac{Y_1}{Y_0} \times \frac{1}{X_1/X_0}}_{\text{TFP}} \times \underbrace{\frac{P_1}{P_0} \times \frac{1}{W_1/W_0}}_{1/\text{TPP}} \quad (3)$$

Any change in the financial condition of the firm/industry (economic profit) reflects the change in productivity and any change in relative prices of inputs and outputs. The first half of the right hand side of (3) is TFP. The second half is the growth in output prices relative to the growth in input prices. More in keeping with the economics literature on productivity, the right half of expression (3) is the reciprocal of what we label "total price productivity" or "total price performance" (TPP), the ratio of input prices to output prices.<sup>5</sup> By tracking TPP along with TFP, we can directly monitor any change in the firm's financial status along with its productivity changes.

Note that financial performance is monitored relative to the base period. If  $R_0/C_0$  is not equal to unity, then the firm is not in long run competitive equilibrium. If  $R < C$  and the firm is making a loss, it is necessary/desirable that the financial condition improve. It would be quite different if the firm started in a substantial monopoly position. Here public policy would be looking for a decline in the

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<sup>5</sup> The change in input prices relative to output prices which we label TPP has been recognized for some time in the productivity literature (but not known by this name). The ratio of an input price index to an output price index is dual to the ratio of an output quantity index to an input quantity index (noted by Jorgenson and Griliches, 1967 citing earlier papers by Siegel, 1952 and 1961), but it is rarely calculated or examined. TPP has been used as an alternate measure of TFP in telecommunications where output measures were hard to obtain (e.g., Chessler 1988). The reciprocal of TPP (i.e., output price index over an input price index) can be thought of as a "terms of trade" concept for a firm and is known as "price-cost recovery" or "price performance" in the management literature on productivity and profitability (e.g. Miller, 1984; Landel, 1983; Sink, Tuttle & DeVries, 1984).

financial position. In brief, one must pay attention to the conditions in the base period  $R_0/C_0$  in assessing the desired link between productivity and financial changes in the firm.

If competitive conditions do prevail, the firm is a price taker for both outputs and inputs and economic profits are zero hence  $R/C = 1$  and  $TFP = TPP$ , i.e., all productivity gains ( $Y/X$ ) are passed on in the form of lower prices for outputs relative to prices paid for inputs. In fact what we call TPP is occasionally used as a measure of TFP because they should be identical under competitive conditions.

One need not assume perfectly competitive conditions; the same relationship holds if there is no change in the market power position of the firm. If competitive conditions change, equation (3) is all the more interesting and useful because we can monitor changes from the initial market power position. For example, suppose a firm is gaining increased market power. It will not pass all productivity gains on to customers, and this will be shown by tracking TFP relative to TPP. If TFP is greater than TPP, the firm has retained part of the productivity gains as increased revenues rather than pass the full productivity gains through to its customers. *In particular, the ratio of TPP to TFP indicates the extent to which productivity gains are shared with customers.*

In what follows, we compare TFP with TPP to indicate the extent of productivity gains, how these are shared between companies and their customers, and hence how the financial condition of the firm changes with productivity gains. The data bases and TFP calculations employ multilateral indices; these enable direct performance comparisons among firms as well as years.

Two applications are shown here, one to major world airlines drawing on updated data for 1986-1995 from Oum and Yu (1995), and a second longer term application to Canadian railways (from Tretheway, Waters and Fok, 1994 and 1997 and Waters and Tretheway, 1997). Both of these studies employ multilateral TFP indices of the form introduced by Caves, Christensen and Diewert (1982). A multilateral index enables direct comparisons of productivity differences between any firm and year, in contrast to the traditional index which only applies to growth rates of productivity for a given firm and not absolute comparison between firms (see Freeman, et al., 1987 for a discussion).

The productivity indices for a multilateral comparison will have selected a particular firm and year as a numeraire, i.e., the input and output quantity indices will be set equal to unity for a chosen firm and year, and the productivity index of all firms (and years) will be expressed relative to the base firm-year. The input and output price indices are constructed as the dual to the input and output quantity indices used in the TFP calculation. This means that numerical values for the input and output price indices for respective firms and years are linked by the revenue/cost ratio for that firm and year, and of course the values of the input and output quantity indices which are measured relative to the base firm. To illustrate:

- Y = output quantity index
- X = input quantity index
- R = total revenues
- C = total economic costs

Then:

$$TFP = Y / X$$

$$TPP = (C/X) / (R/Y)$$

or  $TPP = [1 / R/C] TFP$  (4)

Given TFP for the base firm and year, if  $R > C$  in that year then  $TPP < TFP$ ; if  $R/C$  were unity for the base firm and year, then TPP would equal TFP in that year. Expression (4) also applies to other firms and years as well. Divergence between TFP and TPP from one year to another will determine the change in  $R/C$ . If  $\Delta TFP > \Delta TPP$ , then  $R/C$  improves because the firm has been able to retain part of the productivity gain  $\Delta TFP$ . Conversely, if a firm faces rising input prices and is unable to offset this by productivity gains, then  $\Delta TPP > \Delta TFP$  and the firm deteriorates financially.

Note the interpretation of this "total" price. Just as the output quantity index reflects the combination of all outputs (weighted by their relative importance as indicated by revenue shares), the dual output price index represents the combined effect on the firm's output prices taking the multiple outputs into account. In contrast for example, most discussions of airline price trends focus only on passenger yields. The total price index is a more comprehensive measure of price taking into account pricing of all the services supplied by airlines which were incorporated in developing the output quantity index (below).

### 3. APPLICATIONS TO AIR AND RAIL TRANSPORT

The data for the air application are described in Oum and Yu's (1995) study of productivity comparisons among airlines. Only a brief summary is provided here. The data are a careful and systematic compilation of data on major world airlines, limited to those for which all data categories could be obtained in like fashion. The time period covers 1986 through 1995; 22 airlines are included (one airline, Cathay Pacific, has data only from 1988).

Five categories of output are compiled: (1) revenue passenger kilometres (RPK) of scheduled air service; (2) revenue tonne kilometres (RTK) of scheduled freight service; (3) mail service (measured in RTK); (4) non-scheduled (charter) passenger and freight services, measured as RTK; and incidental services (measured in revenues and deflated by the GDP deflator for the home country; see Oum and Yu, 1992, pp.183-4 for details). The incidental services include a wide variety of services including catering, services supplied to other airlines, and consulting services. The airlines differ substantially in the importance of different output categories. The output index is constructed using revenue shares as weights.<sup>6</sup> The Tornqvist or translog index formula is used.

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<sup>6</sup> Some authors use cost elasticities as output weights rather than revenue shares. This would change the interpretation of the TFP measure. Cost elasticity weights would be correct if we only want to measure "shift" or residual TFP (cost elasticity weights remove the contribution of scale

There are five categories of inputs: (1) labour measured as number of employees; (2) fuel measured in gallons; (3) flight equipment capital is measured by an index incorporating different aircraft types; (4) ground property and equipment capital constructed using the Christensen-Jorgenson (1969) perpetual inventory method (see Oum and Yu, 1995, p.184); and (5) "materials and other" which is a residual or "catch-all" category for all other expenditures by the airline companies. The materials and other category is estimated by subtracting labour, fuel and capital input costs from ICAO's reported total operating costs. Deflating the residual expenditures by an input price index produces and input quantity index for this category.

The output and input categories are combined into multilateral indexes as noted above. The quantity indices are normalized around a particular carrier and year, specifically American Airlines in 1990 and all output, input and TFP indices for other airlines and years are expressed relative to this base.

Oum and Yu (1995) calculated the total economic cost for each airline, i.e., including a capital service price for capital inputs. For this study, dividing the total economic costs by the input quantity index produces the dual input price index. Similarly, dividing total revenues for each airline by its output quantity index produces the dual output price index. Note that the output and input price indices for the base year and carrier will not equal unity unless revenues and total economic costs are equal in that year. This is the long run expectation in a perfectly competitive industry, but a revenue/cost (R/C) ratio of exactly unity will be rare. In the case of American Airlines in 1990 (i.e., the base for productivity comparisons), the R/C is ~~1.082~~ hence the ratio of input to output price indices (TPP) for that year and carrier is ~~also~~ 1.082. The first year (1986) ratio of input to output price indices (TPP) for any airline is determined by the R/C for that airline in that year and the TFP index (which is relative to the American Airlines' base).

For this illustration, we show the results for four airlines: Qantas as well as a representative carrier from North America, Europe and Asia, specifically, American Airlines (the base carrier), British Airways and Singapore Airlines (Figures 1 through 4), but the discussion refers to the pattern of productivity and price trends more generally.

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economies from the TFP measure, Denny, Fuss and Waverman, 1981) If we are content with gross TFP (i.e., all sources of productivity gains are included in the measure), then revenue weights are appropriate. In comparing productivity and prices, it does not matter what the sources of productivity gains are, i.e., the gross measure of productivity is the relevant concept. There is also the issue that one needs estimates of cost elasticities for the shift approach; often these are not available.



Figure 1  
TFP & TPP for Qantas (1986-1995)

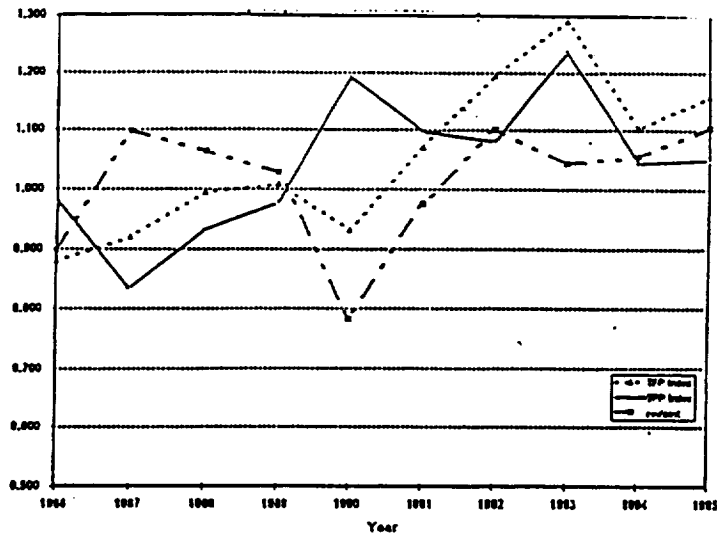


Figure 2  
TFP & TPP for American Airlines (1986-1995)

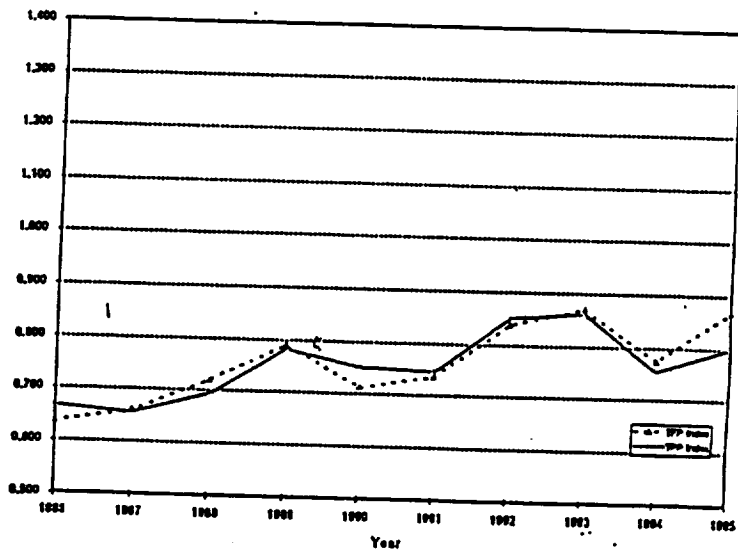


Figure 3  
TFP & TPP for British Airways (1986-1995)

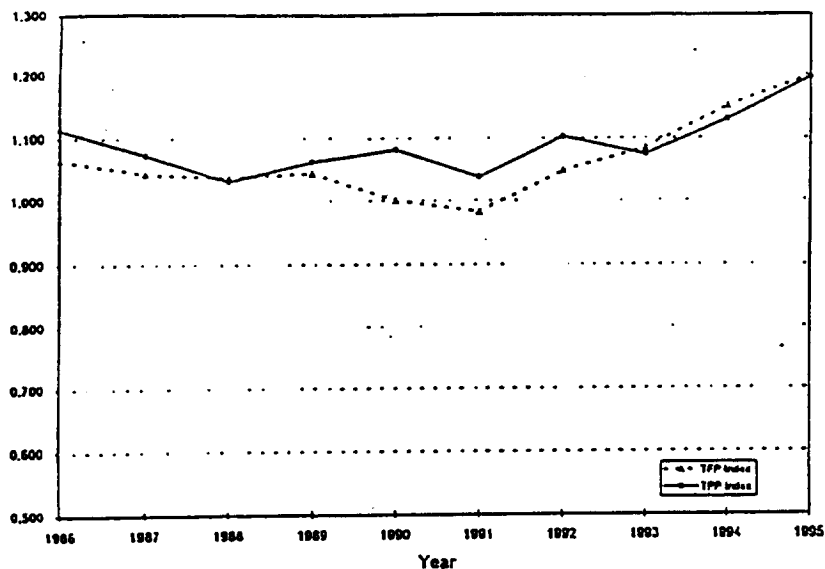
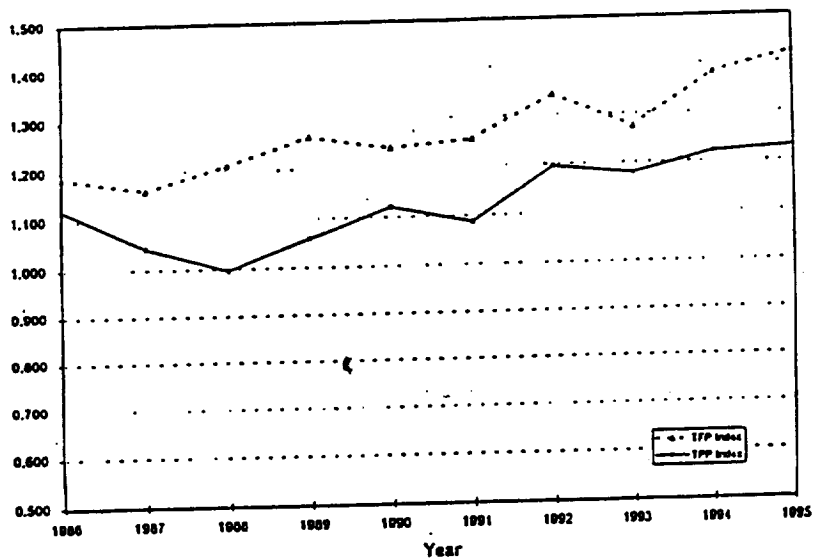


Figure 4  
TFP & TPP for Singapore Airlines (1986-1995)



The data show both similarities and differences across the carriers. Absolute productivity levels as well as rates of growth differ substantially. Nearly all carriers show at least some productivity gains and, in most cases, most of the productivity gains were passed on to customers as indicated by TPP tracking close to TFP. For several carriers TPP exceeds TFP, i.e., input prices have risen faster than output prices and productivity was not sufficient to offset this, hence these airlines' financial condition has deteriorated. For the most part, the Asian carriers have been able to retain some of the productivity gains as improved financial performance, whereas North American and European carriers have been less successful. That is to say, the data suggest greater competitive forces at work in these other markets. This is particularly so for North America where over the sample period every carrier shows input prices paid exceeding the output prices obtained and these price differences are not offset by sufficient productivity gains. This pattern is changed only for two carriers and for the most recent years. That is, the financial condition of North American carriers has deteriorated despite what productivity gains they have been able to achieve. The European story is in between: TFP and TPP track fairly close together but some carriers have been able to retain at least some of the productivity gains to improve their financial condition, notably KLM and Swissair.

The second application is a longer term analysis of productivity and financial performance for the Canadian transcontinental railways, Canadian National (CN), which was government-owned during this period but operated with considerable managerial autonomy, and Canadian Pacific (CP), a private railway. Data cover the period 1956-1995 (Freeman, et al., 1987; Tretheway, Waters and Fok, 1994 and 1997; and Waters, 1997).

For the Canadian railways, data constraints limit our output index to two output categories: passenger and freight services, measured as passenger miles and freight ton-miles, respectively. These outputs are weighted by respective revenue shares, including subsidy payments.

Our aggregate input index is made up of six input categories: fuel and energy, labour, three types of capital inputs and a residual "materials and other inputs." Input quantity indices are constructed for each, with the aggregate index constructed by weighting the input indices by the respective expenditure shares (all input expenditures expressed in consistent dollars). The capital stocks are measured using the Christensen-Jorgenson perpetual inventory method.<sup>7</sup>

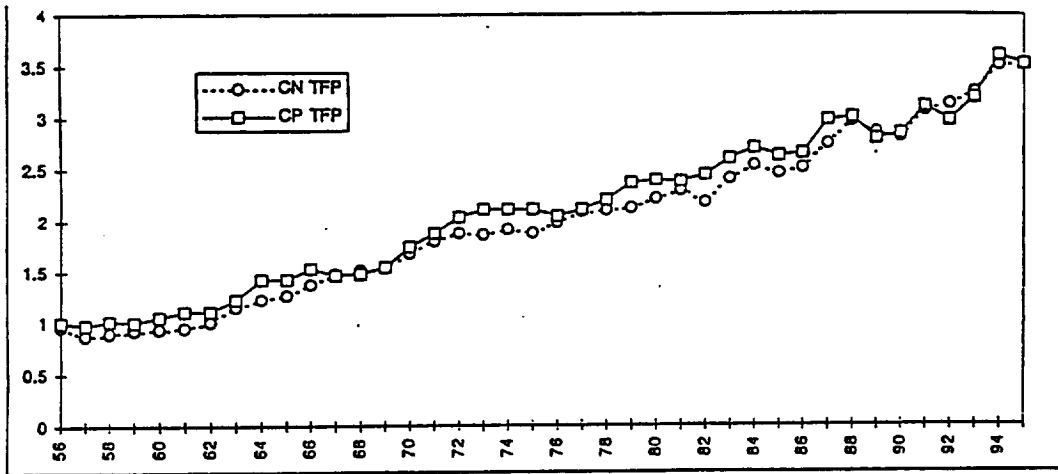
The TFP indices are based for CP in 1956. Both railways shows very similar productivity performance over time (Figure 5), productivity gains of about 3.0 percent per year over the long

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<sup>7</sup> The detailed procedures are explained in Freeman, et al. (1987) and Tretheway, Waters and Fok (1994). The capital stocks include three categories: way and structure capital, equipment capital (rolling stock) and land. Capital stocks were accumulated since the earliest days of the railways (1890 for CP), revalued each year by an appropriate asset price index, plus that year's investment and less a measure of economic depreciation (no depreciation for land). The capital service price includes real depreciation (zero for land capital), the costs of capital (distinguished between debt and equity) less appreciation of the value of capital assets, all this times a tax multiplier which incorporates effective tax rates including the capital consumption allowance for tax purposes.

term.

Figure 5  
Total Factor Productivity Indices, CN vs CP



Source: Tretheway, Waters & Fok (1997) (Updated)

Figures 6 and 7 show the long term trend of TFP and TPP for CN and CP since 1956 (in these figures, TPP has been scaled at unity for CP in 1956, implicitly setting R/C equal to unity for that firm and year). For most of the period since 1956, TFP and TPP track closely together. This is what one would expect from a competitive industry, i.e., most productivity gains, *on average*, are being passed through to customers. But starting in the early 1980s, the two series diverge for both railways, TPP exceeding TFP. That is, real price reductions in services supplied relative to the prices paid for inputs exceed productivity growth. Expressed another way, the railways have more than passed through the productivity gains. The railways are deteriorating financially because they have not been able to retain productivity gains as profits. Recall that the revenue-cost ratio is an economic definition, i.e., a normal competitive return is already included as a cost of doing business. Many railways show improved *accounting* rates of return in recent years, but the real costs of capital rose during the 1980s and 1990s and more than offset the apparent improvement in book or accounting rates of return.

Figure 6  
TFP vs TPP (CN)

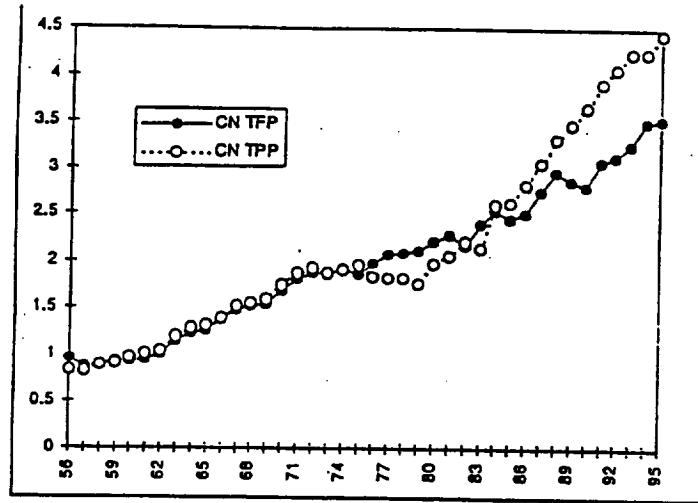
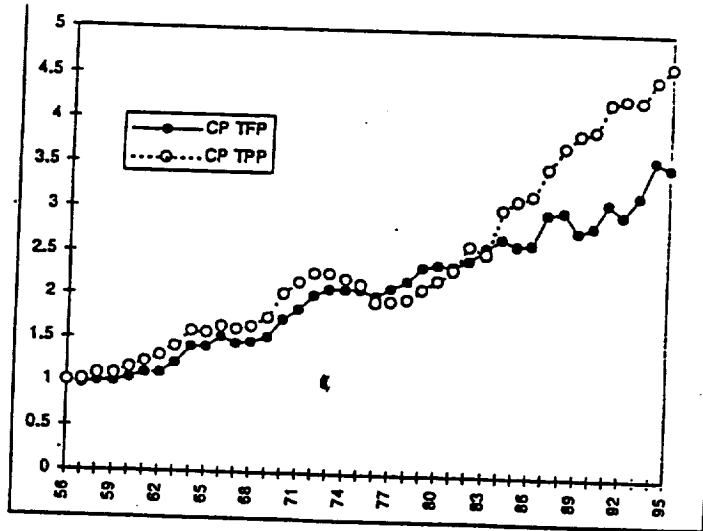


Figure 7  
TFP vs TPP (CP)



Source: Tretheway, Waters & Fok (1997) (Updated)

#### 4. CONCLUSION

This paper compares productivity trends with how they manifest themselves in changes in output prices charged relative to input prices paid. That is, have productivity gains been passed on to customers or retained by the respective companies thereby improving their financial condition? The analysis is done by constructing the dual input and output price indices which correspond to the input and output quantity indices used to calculate total factor productivity (TFP). This price ratio is labelled "total price performance" (TPP) reflecting the fact that these price indices take all output and input categories into account as do the TFP quantity indices. In competitive industries, one expects the growth of input prices relative to output prices to equal productivity gains, i.e., productivity enables the firm to raise output prices by less than the rise in input prices, and competition will force the full productivity gains to be passed on to customers.

It should be noted that the data to make this comparison of prices and productivity sharing are implicit in the data already compiled to make productivity comparisons via index number methods. But researchers have not been making use of the duality relationship between productivity and price changes. This paper shows how existing data for total factor productivity measurement can be used to also reveal productivity sharing and the changes in overall financial performance. This link between TFP and input-output price relationships has been recognized for many years in the management literature (e.g., Miller, 1984; Landel, 1983; Sink, Tuttle and DeVries, 1984) but has not been incorporated into the economics literature on productivity measurement.

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PAPER 886

**Liberalization or Controlled Competition?**  
**The Development of Scheduled Domestic Air Transport in Germany and Japan**  
**Focusing on the Fare System**

REVISED VERSION

by

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◀

# 1 INTRODUCTION

## 1.1 Background and research objectives

For decades domestic air transport markets in Germany and Japan developed in a strictly regulated environment. However, due to political and economical necessities a deregulation process started that led to changes in the market structure especially of scheduled passenger transport. In 1986, the Japanese government changed its air transport policy towards a deregulation policy; in Europe liberalization of air transport was part of the measures to build a common market with equal opportunities for all airlines. In consideration of the results of the rapid deregulation process in the US which caused numerous bankrupts, in Japan and EU it was decided to deregulate the market more gradually. But, whereas in Japan the introduction of new airlines was restricted under law, in Germany, along with the liberalization policy on EU level since the late 1980s, new airlines could enter the scheduled air transport market, starting vivid competition with Lufthansa on some major domestic city-pair relations. In Japan, under the controlled competition system, eight airlines compete in the domestic market. Where competition can be offered, price reductions can take place. Therefore, the analysis focuses on the different approach in deregulating the domestic market in both countries. Regarding the effects of deregulation in the Japanese domestic market, recent developments and changes in market structure and passenger fares for both countries will be investigated, thus answering the question whether controlled competition and the still ongoing process of deregulation can lead to fare competition between airlines as it is the case in Germany.

## 1.2 Thesis on the market's development under competition

As analysis of the aviation markets' development show, in the first stage before implementing deregulation markets have usually monopolistic or oligopolistic structures with one or a few carriers ruling the market under state control. High fare levels and market entry restrictions characterize this stage. If we consider a completely deregulated market, where free market entry has come into effect, the situation can change dramatically for a former monopolist and for customers, because new airlines usually enter the market with lower fares than the established airlines in order to attract customers to the new flight service and to gain market shares. The former monopolist will have to respond with lower prices, in order not to lose customers. The fare levels will fall for all airlines in a market to the customers' benefit.

However, the structure of supply and demand in an air transport market, diversification of products and internal and external factors usually make an oligopoly structure preferable (Beyhoff, 1995). Therefore, in the second stage of market development in a deregulated market there are more start-up and established airlines competing than actually can survive in the long term. In this intermediate period, the prices will be low due to the competition on market shares between airlines and it depends on the company's competitive strength to survive in a price war. The former monopolist usually has some advantages because of its developed service network, economical strength, customers' brand preferences etc. But competition can force the established airline to lower its costs and to restructure the company. For newcomers it is more difficult to survive in a long price war since the airlines have less financial strength and advantages, e.g. economies of scale (Beyhoff, 1995).

The long term development will therefore lead to bankrupts, cooperations and consolidations of airline companies to survive in the market. The result will again be a market structure in which just very few airlines, e.g. mega-carriers with small airlines on feeder service, will remain and rule the market. In this last stage of development due to the lack of competitors the market will fall back into an oligopoly structure and fares could rise to a higher level again, although probably less high than before the deregulation. In how far this development characterizes also the Japanese and German market will be analyzed for the development of market entries and of the fare systems under deregulation.

## 2 DEREGULATION POLICY IN THE EU AND JAPAN

### 2.1 Liberalization of the EU air transport market

#### 2.1.1 Background of political measures and EU market structure

In Europe the call for liberalization of air transport was part of the process to build a single market and the aim to offer customers and operators of airlines equal market conditions and advantages in all EU Member States. There was some controversy surrounding the discussion on deregulation since the Treaty of Rome (March 25th 1957) provided for a common transport policy in its article 74 (Frerich, n.d.a). The supporters of liberalization called for a free transport market by abolishing capacity and fare regulations, whereas supporters of a limitative policy rejected a liberalization policy claiming that the general rules in the Treaty could not be applied in the case of the transport market. They held the opinion that before liberalization, harmonization of the national laws concerning conditions of competition for all transport markets in Europe should take place (Frerich, n.d.a).

The progress in common transport policy was slow until 1985 when the court of Justice ruled that the Council of Ministers had infringed the Treaty of Rome's rules to provide freedom to the international transport services, also aviation in Europe. The Council had failed to set up conditions that allow Community registered airlines to operate without restriction on all services within and between Member States (EuR, 1985). With the court's judgment the authorities were obliged to set up a common European policy for the transport sector. In June 1985 the Commission announced in its White Book that it would complete the Common Market by 1992 (Hayashi, 1995). The European air transport policy's target was then to build a Common air transport market, free of national restrictions and free of discrimination of suppliers (Wenglorz, 1992). In the case of air transport, this meant free access for all EU-registered airlines to all countries in the European Community and their domestic markets. Rules were established guaranteeing freedom of service, freedom of establishment, freedom of market access and freedom of tariffs and fares for all EU-carriers in all EU-countries (Wenglorz, 1992; Lufthansa, 1997a).

#### 2.1.2 Three packages to liberalise the EU aviation market 1987-1997

The first step towards liberalization of the market was initiated by the introduction of the aviation package EC/87/601 on January 1st, 1988. When the liberalization process started, air traffic movement between EU Member States was restricted due to a wide and complex array of national rules and bilateral national agreements. The new EU regulation on fares in scheduled air transport between EU Member States, announced on December 14th, 1987, defined a reference fare on the basis of the normal flight fare in Economy Class or the lowest Flexible Fare and two flexible fare zones (87/601/EWG, 1987). The Discount Fare was between 90% and 65% of the reference fare and the Special Discount Fare's level was 65% to 45% of the reference fare, but strictly limited to certain conditions, restricting the customer groups basically to holiday makers (87/601/EWG, 1987; Frerich, n.d.b). Automatic approval of fares was allowed in the defined flexible zones. All other fares were approved in the "double approval" procedure between two countries. The first package on liberalization was a very cautious step towards more competition in European scheduled air transport. However, because of the close cooperation between airlines and approving authorities concerning pricing, an intentional increase of reference fares could not be excluded and therefore the first package did not lead to significant fare reductions (Beyen/Herbert, 1991).

The second step towards liberalization based on the announcement of the regulation 90/2342/EWG (1990) of the Council on fares that came into effect on November 1st, 1990, employing a fare-zone arrangement for scheduled air services between Member States. In this new fare system, besides keeping the approval system decided in the first package, the "double disapproval" system was introduced for fares above the reference fares, giving more freedom and flexibility to airlines for price setting (Frerich, n.d.b). The Fully Flexible Economy Class Fare could now differ from the reference fare (95%-105%) by a margin of 10% and be freely stipulated by the airlines. The margin for the Discount zone was reduced

in favor of the Special Discount zone (Wenglorz, 1992). The Discount Fare zone differed by a margin of 94% to 80% of the reference fare and the Special Discount Fare differed by a margin of 79% to 30%. The second package brought benefits in fare stipulation, market entry and capacity regulations towards a more flexible and competitive market structure, especially because of the introduction of the double-disapproval system in the Common air transport market (Wenglorz, 1992).

With the third package, regulation 92/2409/EWG, coming into effect on January 1st, 1993, each air carrier can freely set air fares, seat and cargo rates for intra-Community routes. Besides scheduled air service, charter service and domestic air transport of each Member State were included in the new rules for air transport. Basic fares should not be excessively high to the disadvantage of users and they should be in relation to the long-term, fully allocate relevant costs of the carrier with satisfactory return on capital (ICAO, 1996; EWG 2409/92, 1992). Dumping-prices are forbidden. In the case of scheduled air transport, EU Member State authorities can request to deposit a fare level's form before introducing new fares. All other services are free from this obligation (Frerich n.d.a; Giemulla/Schmid, 1996). Regardless of the nationality of an EU-carrier, all EU routes can be served with passenger or air freight services, and start-up airlines including low-cost, low-frills airlines, are encouraged to offer services in competition to established airlines. The third package also included the introduction of full cabotage in the Member States' domestic markets on April 1st, 1997, giving all airlines registered in the EU the right to operate domestic services in any EU Member State other than their own without limitation of capacity (Teuscher, 1994; Giemulla/Schmid, 1996). However, although European carriers are free to operate cabotage-routes, it is not expected that many airlines will offer these services since airport infrastructure and especially slots are limited (W.A., 1997a).

### **2.1.3 Results and unresolved problems**

Since 1993 when the third package of liberalization came into effect, 20 new airlines were launched and remained in the market with the effect that under growing competition fares have fallen. But still a high pricing policy for Fully Flexible Fares for many European airlines can be observed. Considering the experience of market disruption in the US after a sudden deregulation, the deliberately phased three stage liberalization in the EU did not lead to spectacular fare reductions nor any disappearance of an important carrier (DG VII, 1997). Between 1993 and 1996 the number of European routes rose from 490 to 520 and 30% of Community routes are now served by two operators, 6% by 3 operators and more. The effect that new carriers entering the market usually was that the dominant carrier's market share fell to the advantage of the other carriers (DG VII n.d.).

One of the most serious and yet unresolved problems in the liberalised European air transport market is the slot allocation. Generally speaking, slots are given to airlines on the basis of the "grandfather right" (historical right), guaranteeing continuous flight services for airlines and customers (Wenglorz, 1992). However, in a deregulated market, competition and new suppliers cause an increase in traffic, which leads to capacity bottlenecks at all important airports. The limitation of slots and the "grandfather right" principle prevent airlines from entering important routes and from competition with established airlines, causing serious market entry barriers for new competitors in a market that should provide equal chances for all airlines (Wenglorz, 1992). Another problem is the difference in airport charges depending on the airport. At present, charges are levied on facilities, parking, refueling, storage and freight services by airports on carriers, varying considerably from airport to airport, and reaching from 5% up to 10% of operational costs of airlines (DG VII, 1997). Since these charges have a heavy influence especially on smaller airlines and can be a disincentive to new operators, the Commission seeks to create a framework on basic rules governing the levy of charges according to the principals of non-discrimination, cost-relatedness and transparency (DG VII, 1997). An imbalance in preconditions in the Common market is apparent for privatized airlines competing with state-owned airlines. In particular, subsidies for public airlines cause a competitive imbalance between airlines operating in the European market. Lufthansa (1997b) found that since the beginning of the 1990s, Air France received 6 billion

DM of subsidies, Iberia 2.5 billion DM, Sabena 1.8 billion DM, Olympic 3 billion DM and TAP Air Portugal and Air Lingus each 400 million DM. But it must be mentioned that also Lufthansa was a state-owned airline until it was partially privatized in October 1994 and only in October 1997 the rest of the 38.9% directly or indirectly state-owned Lufthansa-shares were sold (Lufthansa, 1996).

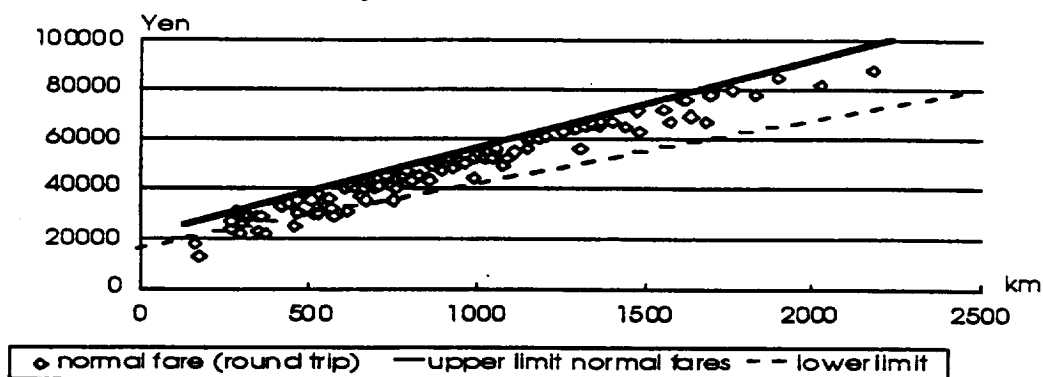
## 2.2 Deregulation and controlled competition in Japan

Until today concerning airlines' licensing, route and fare approval, the Japanese market remains under the control of the Ministry of Transport (MoT). The Civil Aeronautics Law, which governs the industry, requires that airline companies obtain government licenses to enter the market. Due to the 1970 Cabinet Meeting Resolution "Concerning Airline Operations" and due to the Notice from the Minister of Transport in 1972, it was introduced a three-company system into the domestic market, resulting from the consolidation of Japan Domestic Airlines (JDA) and Toa Airlines (TA). The so-called 1970-1972 airline regulation system was intended to secure and nurture transport capacities of the airline industry by establishing a segmented business base for each firm. This sudden policy change was said to be brought about by strong political pressure from particular corporate groups, and shows that government policy could be moved by influential private bodies (Yamauchi, 1995). Trunk route markets (Sapporo-Tokyo-Osaka-Fukuoka) grew much faster than other "local" markets and became a source of internal cross-subsidization. With these lucrative markets, the consolidation of the former two small airlines into one big company made it possible to derive economies of scale and allowed TDA to obtain the ability to use money from trunk routes to compensate deficits from local routes. The same worked for JAL and ANA. JAL could make up losses in international services and ANA could cross-subsidize losses in domestic local routes by using the surplus in trunk routes (Yamauchi, 1995).

In the late 1970s and early 1980s the deregulation of the US air transport market had effects on the Japanese policy towards more liberalization. The Fair Trade Commission called for more relaxation in the regulations in aviation fields. The role of governmental intervention protecting airlines functioned adequately up to this stage, but also caused the high cost tendency of airlines (Yamauchi, 1996). The deregulation process started to promote better competition conditions for Japanese airlines in international and domestic markets. The Japanese government started negotiations with the US on the entry of NCA in the north pacific market and the Interim Agreement of 1985 admitted the new entry of NCA (Japan Cargo) allowing other new carriers to start scheduled passenger services of both Japan and the US and strengthened calls for the liberalization of the Japanese domestic market too. In 1986, the Council for Transport Policy submitted its final report concerning the future operating status of airlines. The new policy focused on the promotion of double tracking and triple tracking corresponding to the size of demand on each route and the status of airport facilities. Furthermore the necessity of the major airport's capacity expansion was pointed out. Concerning the domestic market, the competition should be promoted by new entries to particular city-pair markets. While JAL was only in the domestic trunk routes markets (Sapporo, Tokyo, Osaka, Fukuoka, Naha), it now also operated in dense local routes (Yamauchi, 1995). But deregulation measures were not completed since the institutional framework concerning entry licensing and the fare approval system remained unchanged. The new "promotion of competition" policy rather sought deregulation within the range of administrative operation without changing the licensing system for new entries or the approval system for setting fares (Yamauchi, 1995). Regulation was even strengthened, because the administration decided which route would become a double track or a triple track, and which carrier would enter there. From the customers' point of view, the new policy brought no benefits because the fares did not decrease in a significant way. Whereas in Germany the EU policy also brought changes to the entry licensing and fare approval system, the Japanese fare approval and entry licensing system under the so-called "controlled competition" policy remained unchanged (Yamauchi, 1996). Competition always was service or aircraft size-related, whereas the airlines' fares did not show any trend towards competition. In 1994, the approval system was partly deregulated, allowing discount rates up to 50% and charges for using special equipments. Then in June 1996, a zone fare system

was adopted that allows Japanese airlines to set passenger fares within a certain range freely, similar to the regulations in the EU second package of Common air service. In peak travel periods the carriers can set relatively high prices, and offer promotional fares during the off-peak period.

Figure 1: Fares in the zone fare system



(JR Group, 1997b)

Before the zone fare system was adopted, the upper limit of the permitted fare zone was calculated on the airlines' cost and profit basis of the prior year's actual balance sheets. However, in the now applied system the upper limit is set and calculated by the MoT on a cost and profit target basis that is set on a lower level than in the before applied system, in order to encourage airlines to reduce costs and to initiate rationalization measures to increase their profit. The calculation of the cost and profit targets set by the MoT is now the background of the fares' upper limit - called standard (or normal) fare. The lower end of the normal fare range is set at level 25% less than the upper limits. The carrier can set discount fares at a maximum of 50% below the lower limit. Therefore, the lowest discount fare could be set at 62.5% lower than the standard fare (Yamauchi, 1996). Within these limits the airlines can freely decide fare levels, which are approved automatically. Most normal fares on middle-hauls and long-hauls are close to the then upper fare limit whereas in the case of short-hauls - mostly routes to remote islands - the fare level is lower and closer to the lower end of the range in order to meet the social minimum rather than for economic reasons. The licensing system for new entries is still strict and new airlines which could be interested in using the whole range of pricing in the zone fare system have not been able to enter the market yet. Therefore, deregulation measures brought a certain price diversification but did not lead to downward pressure on prices. However, the situation is likely to change from September 1998, since several new airlines were established and will enter the market. In order to gain market shares, the newcomer airlines could cause a decrease in fares within the regulation frames and put established airlines under pressure to reduce their fares, too. In addition, the track system, that by definition linked the number of airlines to the annual demand on routes, was abolished on April 1st, 1997 and now airlines can decide freely whether to enter a city-pair market.

### 3 INFLUENCE OF DEREGULATION ON THE DOMESTIC MARKET AND FARE LEVELS IN GERMANY AND JAPAN

#### 3.1 Market entries and structural changes in the domestic markets

##### 3.1.1 New airlines in the markets

Since the liberalization process started, the number of airlines in Europe increased from 99 to 156 carriers for scheduled services (W.A. 1997a). The new policy also had effects on the German market, bringing Deutsche Lufthansa's monopoly to an end. Before 1987, it was just the flag carrier Lufthansa and a few regional airlines, as subsidiaries or cooperating airlines, that operated in the domestic market (Soltwedel, 1986; Stotzer, 1991). With

liberalization of capacity regulations and route selection, freedom of pricing and freedom of establishment, other airlines entered the market. But only a few airlines have used the cabotage rights since 1992, operating only 22 cabotage routes in Europe (Reuter, 1997a).

Lufthansa competitors in the domestic market are newly established airlines, or airlines that emerged out of other smaller regional carriers. The domestic scheduled service Augsburg Airways (IQ), Deutsche British Airways (DI), Eurowings (EW), Hamburg Airlines (HX) and the British Debonair are worth mentioning. Deutsche BA was launched in June 1992 by three German banks Commerzbank (19%), Bayerische Vereinsbank (16%), Berliner Bank (16%) (=51%) and British Airways (49%), and operates its flights from two hubs, Muenchen and Berlin/Tegel (Deutsche BA, 1997a). However, since April 1st, 1998, Deutsche BA is a 100% subsidiary of British Airways (Deutsche BA, 1997d). The airline's strategy is to offer a high level of service while keeping costs down in order to achieve lower fare levels to attract customers. In 1995/96 Deutsche BA was able to increase its market share by 19% and carried 2.2 million passengers earning revenues of DM 492 million (Deutsche BA, 1997a). Hamburg Airlines and Eurowings compete as regional airlines with Lufthansa in the German and European market. The Dortmund and Nuernberg based Eurowings is the largest independent airline offering scheduled and charter service. In 1996, 264,000 passengers were recorded in charter service, 870,000 in international scheduled traffic and 766,000 passengers in domestic flight service (W.A. 1997d). As Delta Airlines reduced their service from Frankfurt, Eurowings could get necessary slots to operate flights between Frankfurt and Berlin, thus ending Lufthansa's monopoly on the most important domestic route in May 1997. The British low-cost carrier Debonair, not included in table 1, entered the German domestic market in June 1996 on the Moenchengladbach-Muenchen route (Reuter, 1996a).

Table 1: Airlines competing in the German domestic market in 1995

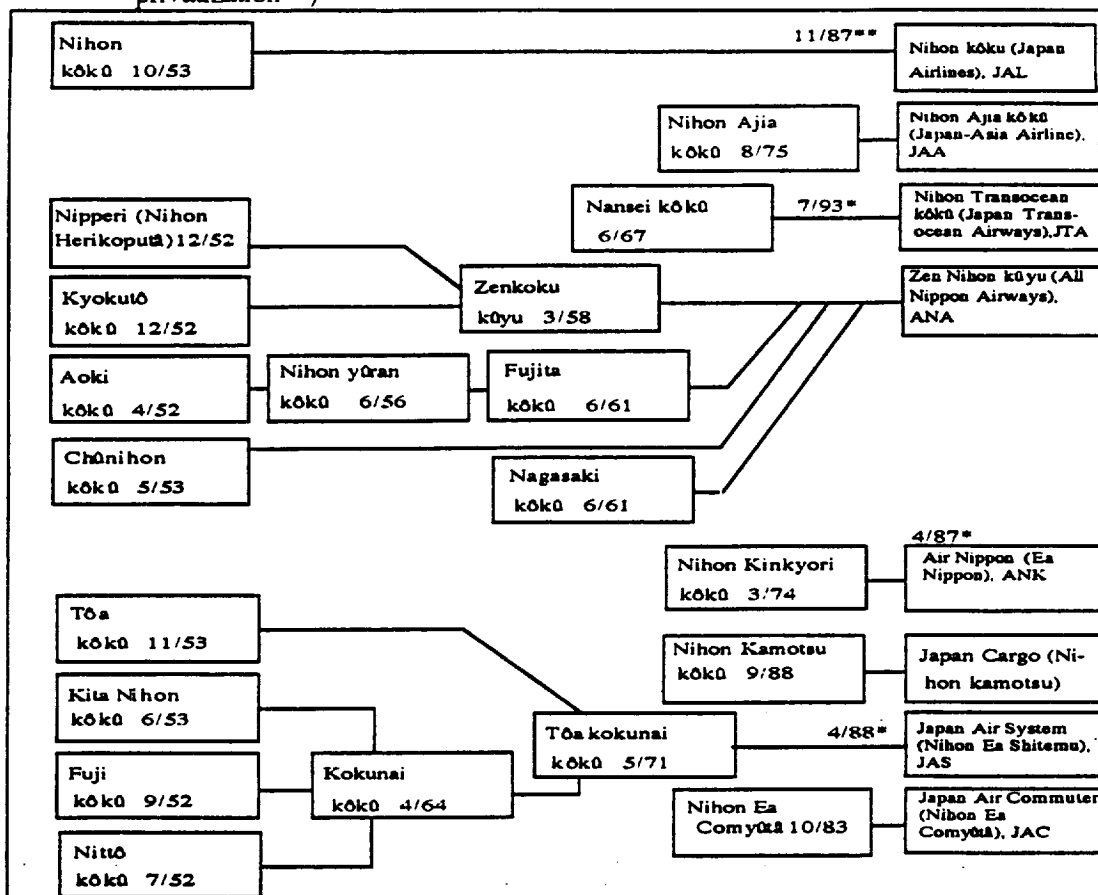
	LH (dom.)	DI	HX	IQ	EW
Year of foundation	1927	1992 as Delta Air Regionalflugverkehr GmbH	1988	1980 as airline on request, 1986 as scheduled airline	1993 as NFG, Nuernberg (1975) and RFG, Dortmund (1976)
Turnover in Million DM	2528	492	-	31	41
Passengers (1000)	13200	2200	200	100	1800
Number of aircrafts	269	21	9	7	35 (1997)

(Lufthansa 1996; Deutsche BA, 1997a; Eurowings, 1996; Augsburg Airways, 1997; Hamburg Airlines, 1997; ICAO, 1996)

As figure 2 shows, there have been more airlines in domestic service in Japan than in Germany and operating for a longer time under MoT's controlled competition policy. In 1952, Japan Airlines (JAL) was established as a major private company operating in domestic markets. The following year, the government decided to reform JAL to a semi-public corporation to foster the company as a national flag carrier and to strengthen JAL's international competitiveness. At the same time, several private airline companies were founded, but this was soon followed by bankrupts and consolidations and in 1957/58, the two biggest carriers of these merged to All Nippon Airways (ANA), the second major but purely private carrier (Yamauchi, 1995). Some of the regional carriers founded in the late 1950s merged into ANA and two of them - Japan Domestic Airways (JDA) and Toa Airways (TA) - merged into TOA Domestic Airways and then changed name to Japan Air System (JAS) in 1988. There are presently eight scheduled airline companies in Japan: JAL, ANA and JAS, Air Nippon (ANK), Japan Asia Airline (JAA), Japan Transocean Airways (JTA), Japan Cargo (NCA) and Japan Air Commuter (JAC) (Takahashi, 1992). However, most of the mentioned airlines belong to one of the three airline groups, namely the JAL-group, including JAA and JTA, the ANA-group with ANK, and the JAS-group, including JAC. This group structure is one of the main reasons of the mostly homogenous fare levels that will be shown later. But market and fare structure could change, since new airlines have been approved by the MoT.



Figure 2: The Japanese airlines 1952-1997 (month/year of foundation, change of name\*, privatization\*\*)



(Takahashi, 1992; MoT, 1997)

Six new airlines, namely Skymark Airlines Co., LTD., Hokkaido International Airlines Co., LTD., Japan Pacific Airlines Co., LTD., Southern Cross Co., LTD., JAL Express Corporation and Harlequin Air Corporation will start service from 1998 on. Skymark Airlines was founded in November 1996 by the main share holders HIS Corporation, a Discount Travel Agency (53.5%), Oriks, a leasing corporation (20%), GVC, No.1 Investment Union, (9.2%) and the president of Skymark (5%). It is planned to start service with three aircraft a day on the Haneda (Tokyo)-Fukuoka route from September 1998, followed by increasing the service on domestic flights and international charter flights. The company plans to enter the market with fares 50% lower than the established airlines. Hokkaido International Airlines was founded in November 1996, too, and will start service between Tokyo and Sapporo from April 25th, 1998 and from October 31st, 1998 between Osaka and Sapporo. The airline also plans to offer short international charter flights in the future. The fare for Tokyo-Sapporo will be approximately DM 403, that is nearly half the price JAL, ANA and JAS offer on this destination. For Osaka-Sapporo the ticket will cost approximately DM 596 that is 60% of established airlines' prices. Japan Pacific Airlines, founded in May 1997, plans to start service in June 1999 on international charter routes in the northern Mariana islands. Southern Cross Co., LTD. was founded in July 1997 and plans to start service in March 2000 on the Tokyo-Naha route and later on several international routes in Asia. The JAL Express Corporation was founded as a subsidiary of JAL in April 1997 for operating JAL's low profit routes from April 1998 in order to cut JAL's personnel costs 20% down. Until the beginning of the next century, JAL Express will operate 15 to 20 aircraft and plans to enter both the 767 trunk routes and short-haul international routes. The shares of Harlequin Air Corporation, founded in January 1997, are 100% owned by JAS. The reason for founding the company is to cut down costs, but also to

develop niche markets, since the airline will fly on routes from Fukuoka as a regional airline and as charter airline on international routes, and it will also serve on low profit routes, like JAL Express Corporation. By founding this new subsidiaries, JAL and JAS follow the same outsourcing policy like European airlines. But especially the market entry of the other new independent airlines could lead to a reduction in fares, since they will have to compete with the established airlines in the domestic Japanese market.

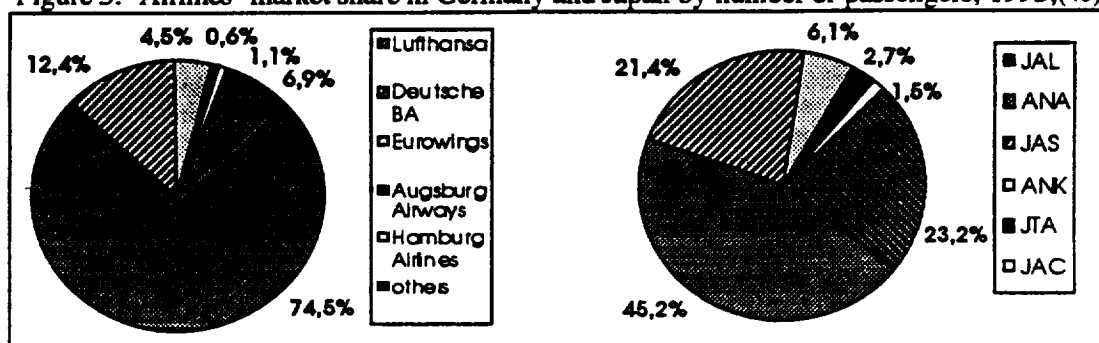
### 3.1.2 The domestic markets' structure

The Japanese domestic air transport market, with 78,100,754 passengers in 1995, is 5 times bigger than the German domestic market (MoT, 1997). In Germany in 1995, out of the overall 90,047,000 passengers starting their flights from Germany, 20,285,312 passengers flew on intra-European routes (22.5%) and 17,714,811 passengers were bound for domestic destinations. While in Germany, with a population of 81,538,603, one out of five persons took an airplane for a domestic journey in 1995, in Japan with a population of 124,322,801 about 62.8% or 1.6 out of two people traveled by airplane inside Japan (Imidas, 1995; Statistisches Bundesamt, 1995). Moreover, the most frequented Tokyo-Sapporo route in Japan shows an annual figure of 7,631,516 passengers and has 5.18 times more passengers than Germany's busiest domestic route Frankfurt-Berlin with annually 1,434,661 passengers (Statistisches Bundesamt, 1996). To comply with growing demand in the Japanese domestic market, 23 out of 240 routes are served by three airlines and 37 by two airlines (MoT, 1997). In 1995, among the 78,100,754 passengers on Japanese domestic routes, 38,833,673 passengers traveled on triple tracks (49.72%), 19,901,848 on double tracks (25.48%), and 19,365,233 on single routes (24.8%) (MoT, 1997; NKK, 1997). Whereas in Japan double and triple track routes were established as a part of the MoT's controlled competition policy, in Germany the introduction of parallel served routes started automatically with the opening of the market, depending on the availability of slots. In Germany, new airlines are now competing with Lufthansa on 24 routes. The German market is especially interesting for new airlines because of its structure. Compared to other European countries, Germany has most inhabitants and can be expected to have a larger market potential. The domestic scheduled market in Germany is not only a feeder market for intra-EU flights but is also an important starting-point for international flights. Almost 24% of all EU external flights start in Germany. The network of well-developed airports spread all over Germany offers the opportunity to establish flight services between secondary markets such as Hamburg, Koeln, Duesseldorf, Berlin or Stuttgart for domestic services or as feeder-services for European hubs. European airlines such as Air France or British Airways, organize connection flights from Germany to their hubs themselves or in cooperation with German partner airlines, e.g. Eurowings (for Air France or KLM). Furthermore, the continuing high cost and price level of the market leader Lufthansa offered a chance of pricing competition to low cost oriented new airlines (Loppow, 1997a). Considering the status quo and the further development in the German domestic market, the Lufthansa expects that "Germany will become the battlefield of the European liberalization" (Loppow, 1997a).

Since several independent and small low-cost airlines such as Debonair, Easy Jet or Virgin Express entered the profitable business routes in the European market, rising competition favors setting up alliances or code-sharing etc. cooperation agreements for established airlines. Rather than operating cabotage routes, they join with a domestic airline, saving both partners from investing in their infrastructure in order to enter the new market (Reuter, 1997a). The most successful airline in setting up cooperations, financial linkages or franchise agreements is so far British Airways. The airline entered markets in France, becoming number two in domestic air traffic, based on a network of partnerships with the airlines TAT and Air Libert  (Reuter, 1997a). By establishing a network of subsidiaries and partners, BA developed a network with 100 aircraft of small regional airlines flying in behalf of BA on less profitable routes. The franchising network with five British airlines (City Flyer, Manx, G-B Airways, Loganair and Maersk) gives advantages to both sides, since the partners can use the brand name British Airways Express and can use BA services (frequent flying program, reservation etc.), whereas British Airways itself can enlarge its network

without costs and attract more customers to its long-haul programs, using the franchise partners for feeder services (Kommission der EG, 1996). Lufthansa followed the British Airways example, and founded together with five international airlines the largest worldwide so-called "Star Alliance" and is partner of several European regional carriers, e.g. British Midland. It established Lufthansa CityLine GmbH as a subsidiary for less frequented European and domestic routes and the so-called "Team Lufthansa" for cooperation with Contact Air, Cimber Air and Augsburg Airways on a franchise basis (Reuter, 1997a; Lufthansa, 1997d). Augsburg Airways operates as a Lufthansa franchise partner on the routes Muenchen-Dortmund, Muenchen-Erfurt, Muenchen-Leipzig-Halle and Augsburg-Frankfurt, although the franchise agreement with Augsburg Airways caused opposition by Eurowings, which operated routes in behalf of Lufthansa, too, claiming the franchise project to be the beginning of competition on Eurowings "home market" (W.A. 1996a, Reuter, 1996b). As a result of the new structure, Lufthansa itself decided to end the contract with Eurowings at an early age. Furthermore, it was reported that Lufthansa plans to establish a new low-cost airline in order to outsource more loss-making intra-German and European services from its business unit "Lufthansa Passage AG". Like British Airways, Lufthansa plans to concentrate more on long-haul markets (Beyhoff, 1995). However, Lufthansa has also successfully used predatory measures in the past in order to resist competition. Aero Lloyd (Charter Airline) and German Wings tried to enter the scheduled airline market in the late 1980s, but Lufthansa could oust both airlines by blocking slots, raising capacity on parallel routes etc. In the end, Aero Lloyd concentrated again on the charter market whereas German Wings went bankrupt (Beyhoff, 1995; Stoetzer, 1991). Concerning the new competition in the domestic market, Lufthansa pointed out that it "...will not permit to be ousted from its home market" (Lufthansa, 1997a). This statement shows that any new competitor in the German domestic market will have to face countermeasures by Lufthansa, since more than half of the company's turnover proceeds are accounted for in the European region or Germany (Nitinger, 1997). One internal measure to compete better with new airlines was to reduce the cost per offered seat-km below 0.15 DM with the so-called "Program 15", to outsource low-profit routes operating via franchise partners or subsidiaries and to reduce costs by 14% (1.5 Billion DM) by the year 2001 (Reuter, 1997b).

Figure 3: Airlines' market share in Germany and Japan by number of passengers, 1995,(%)



(MoT, 1996; Lufthansa, 1996; Deutsche BA, 1997a; Eurowings, 1996; Augsburg Airways, 1997a; Hamburg Airlines, 1997a; ICAO, 1996)

As figure 3 shows, with regard to annual passenger shares by airline, the German market is still dominated by Lufthansa. The company leads with 74.5% of all passengers flown on domestic routes in 1995, followed by Deutsche BA (12.4%) and then others 6.7%, small regional carriers which operate under Lufthansa contracts. Actually Deutsche BA claims to have a market share of 35-38% in Germany, but this implies the airline's domestic routes operated in competition to Lufthansa, not the overall market volume in number of passengers (Loppow, 1997b; SZ, 1997). In Japan in 1995, ANA claimed about 45.2% of the domestic market, followed by JAL (23.2%), JAS (21.4%), ANK (6.1%), JTA (2.7%) and JAC (1.5%) (MoT, 1997). ANA has the major share in the domestic market, but regarding the development under controlled competition, the airline lost 10% market shares between 1985 and 1995 whereas JAL gained 5%, and JAS basically kept its 20% to 21% during the whole

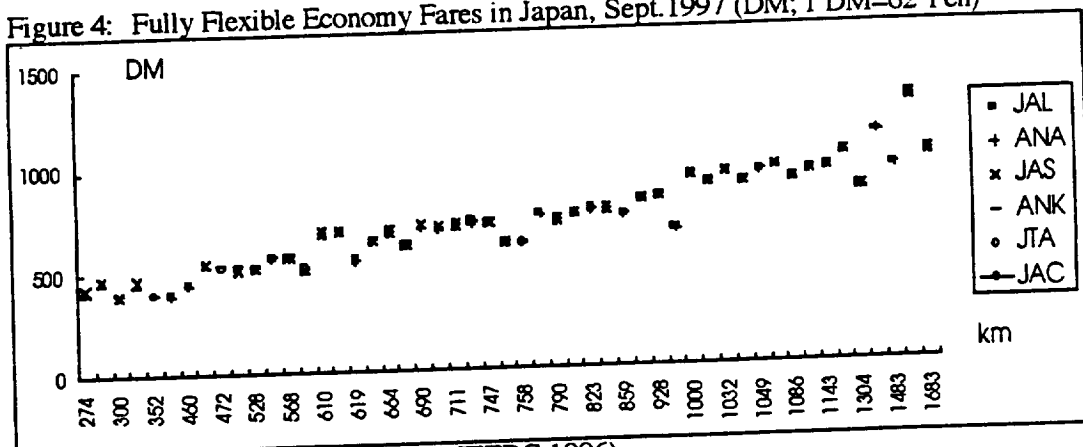
period. Besides JAL, the regional carrier ANK is the winner of the controlled competition system since it could increase its market share from 2.4% in 1985 to 6.1% in 1995, while the other regional carriers JTA lost shares and JAC remained in a 1.5% market share (MoT, 1997). The loss of JTA though was a result of giving low-profit routes to Ryukyu Air Commyutâ, while keeping the profitable regional routes and the Tokyo-Naha route. The whole market volume increased in this period of ten years by 78%.

### 3.2 Comparative analysis of fares: Domestic passenger fares

#### 3.2.1 Economy fares in Germany and Japan

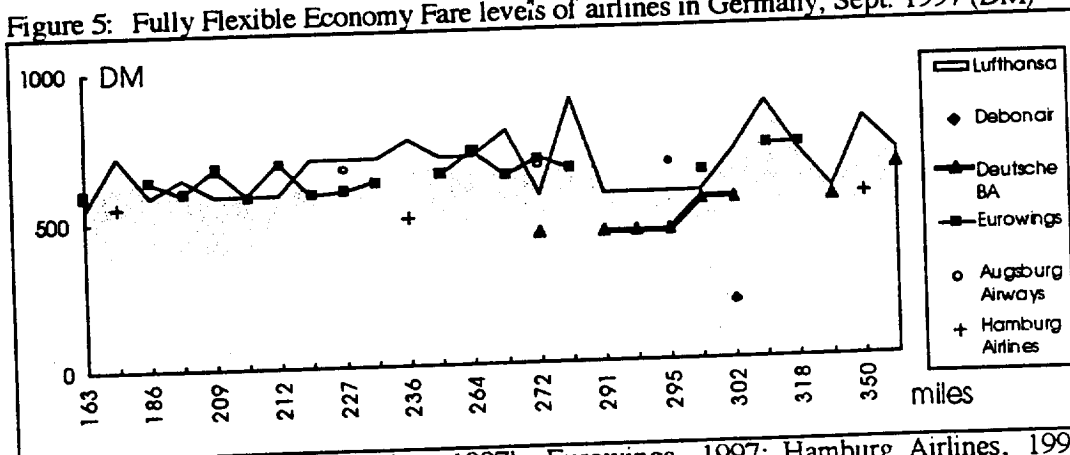
In the German domestic scheduled market, new entries and a decline in fare levels have been observed since liberalization started, whereas in Japan the double and triple track system and the introduction of the zone fare system has not lead to a remarkable reduction in fares or to entries of new airlines until the end of 1997. Under the system of controlled competition it was not necessary and partly not possible for airlines to apply pricing strategies. Differences in fare levels on double or triple track routes are marginal between the three market leading airlines ANA, JAL and JAS. This situation did not change even with introduction of the zone fare system. Therefore, customers' expectations to benefit from a deregulated fare system have not been realized. In Japan, a connection of distance and fare levels can still be observed. As we can see in the comparison of fares in Japan and Germany, in Germany, freedom of pricing and market entry of new airlines favor a more vivid fare competition on routes operated by two airlines (figure 4 and 5).

Figure 4: Fully Flexible Economy Fares in Japan, Sept. 1997 (DM; 1 DM=62 Yen)



(JR Group, 1997a; JR Group, 1997; JTERC 1996)

Figure 5: Fully Flexible Economy Fare levels of airlines in Germany, Sept. 1997 (DM)



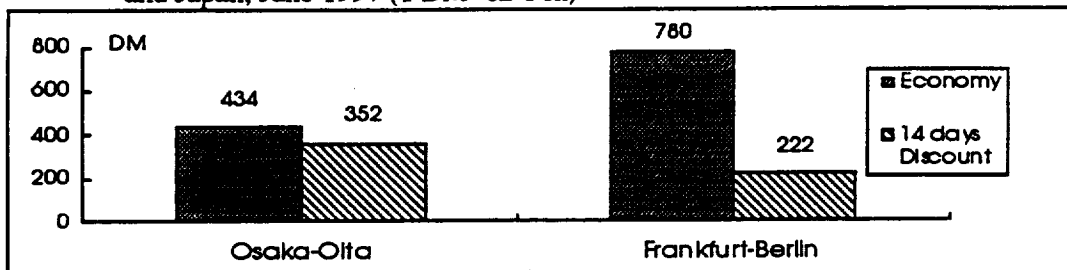
(Lufthansa, 1997c, Deutsche BA, 1997b; Eurowings, 1997; Hamburg Airlines, 1997b; Augsburg Airways, 1997b)

As a result, Fully Flexible Economy Fares on return tickets of airlines competing on the same route vary from 0% to 4% in Japan, whereas in Germany, the fares vary in a span of 4% to 35% on the same route. Particularly important for Lufthansa's price setting is whether Deutsche British Airways operates the same route. In this case Lufthansa fares fall to almost the level of Deutsche BA's fares. Although the growing competition in Germany forced Lufthansa to decrease its fare level, in comparison to Japanese pricing structures the Fully Flexible Economy Fares for return tickets in Germany usually show a higher fare level for equivalent distances. Deutsche BA and Eurowings fares have nearly the same fare level as Japanese airlines on equivalent route distances. Whereas on routes to Berlin, Lufthansa introduced a special Economy fare ("Spree Tarif"), which is not equivalent to the most Flexible Economy Fare and therefore not shown in figure 5, Deutsche BA has reduced its Full Flexible Economy Fare on these destinations. This explains the discrepancy of fare levels between Lufthansa and Deutsche BA on some common routes. The fare comparison on the Duesseldorf/Moenchengladbach - Muenchen route (302 miles) - as an example for a low cost carrier's route - shows that Debonair offered class-free tickets for DM 159 one-way or DM 318 for return tickets whereas the lowest available Flexible Fare without restrictions in the case of Lufthansa costs 590 DM and with Deutsche BA 540 DM. Lufthansa observed a steep incline of Economy class bookings not only due to larger numbers of private travelers but also due to a migration from higher classes to Economy Class. Although the price gap between Lufthansa and other airlines is sometimes large, Lufthansa still counts on customers willing to pay an additional 15%-20% "brand surcharge" in the German core market (Nittinger, 1997).

### 3.2.2 Discount fares

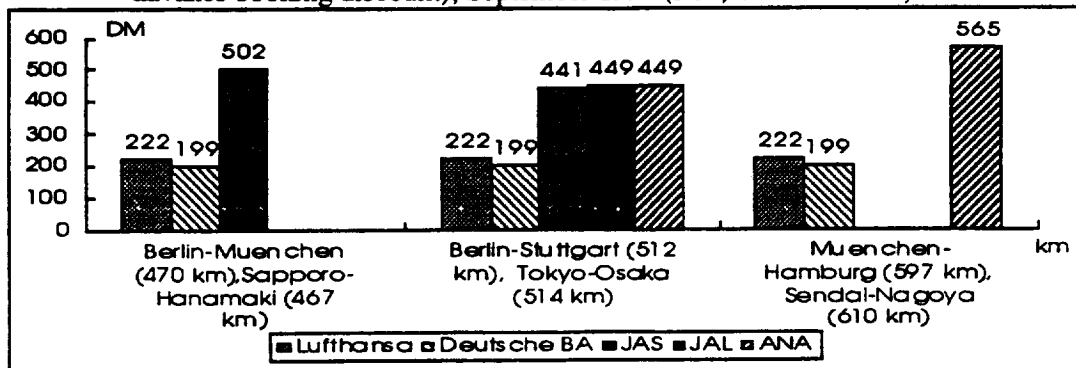
In Germany, generally speaking, four types of Discount Fares can be distinguished. The lowest Discount Economy Fare available is a 14 days in advance booking Discount Fare with restrictions on booking, duration of stay etc. The second Discount Economy Fare has an obligation to book 7 days before the trip starts.

Figure 6: Comparison of Discount Fares and Fully Flexible Economy Fares in Germany and Japan, June 1997 (1 DM=62 Yen)



(JR Group, 1997b; Lufthansa 1997c)

Figure 7: Comparison of Japanese and German Discount Economy Fares (14 days in advance booking discount), September 1997 (DM, 1 DM=62 Yen)



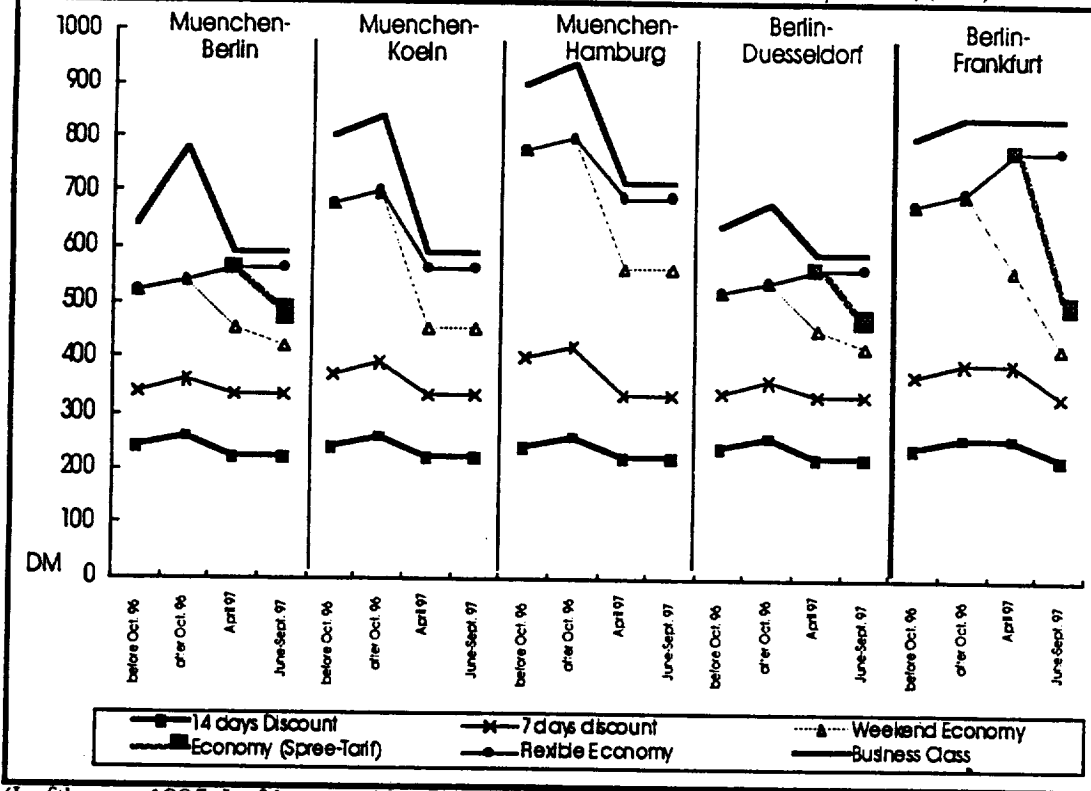
(JR Group, 1997c; JTERC, 1996; Lufthansa, 1997c; Deutsche BA, 1997b)

This type can be found in the case of Lufthansa and Deutsche BA. Some other airlines like Eurowings and Augsburg Airways have an equivalent discount level, but without the 7 days in advance booking clause. The Weekend Discount Economy Fare and the so-called "Spree Tarif" on routes to Berlin are available only with Lufthansa. Deutsche BA introduced a "Hauptstadt-Tarif" (Capital fare). Special Discount Fares on certain routes or for certain age groups or seasons exist with almost any airline. In Japan, there are different types of discount fares in existence, e.g. a 28 days in advance booking discount fare, that implies a discount rate of 50%. But since the conditions of Discount Fares vary among airlines in both countries, the lowest Discount Economy fare allowing a comparison is the 14 days in Advance Purchase Economy Discount Fare. The comparison of Fully Flexible Economy Class Fares in Japan and Germany has shown that the fare level is mostly higher in Germany than in Japan. However, as figures 6 and 7 show, in the case of discount fares, the result is quite different. The figure shows Full Flexible Economy Fares and the lowest Discount Fare in common - the 14 days in Advance Purchase Economy Discount Fare - for the Osaka-Oita route in Japan and the Frankfurt-Berlin route in Germany. Both routes have equivalent distances (460-470 km). Discount fares in Germany can be 60% to 73% lower than the Fully Flexible Economy Fares. In Japan, the difference is just 10% to 20%. Accordingly, the Discount Fare for Osaka-Oita is 19% lower than the Fully Flexible Economy Fare, whereas the discount rate on the Frankfurt-Berlin route (Lufthansa fare) is 71% lower than the Fully Flexible Economy Fare. Considering Lufthansa's three types of Discount Fares with different conditions, and then choosing the Weekend Economy fare (DM 420) for comparison, the lowest Discount Economy Fare still reaches a 47% discount rate. As a result, the Fully Flexible Economy Fares can be considered more customer friendly in Japan, but Discount Fares in Germany give customers with flexible flight schedules a greater opportunity to fly at a low fare.

### **3.2.3 Competition on fares in the German domestic market**

**3.2.3.1 Development of Lufthansa fares under competition with Deutsche BA**  
The development of fare competition will be analyzed for some of the 15 common routes of Lufthansa and Deutsche BA or Eurowings. These routes connect the most important cities in Germany from Frankfurt, Berlin or Muenchen. Deutsche BA and Eurowings operate each on seven routes in competition to Lufthansa or its franchise partner. Since the increasing competition in the German domestic market caused the liquidation of the regional carrier Hamburg Airlines by the end of 1997 after the airline had tried to merge with Augsburg Airlines, only Deutsche BA and Eurowings can be regarded as important Lufthansa competitors, especially on trunk routes (Rodrian, 1997). The annual number of passengers carried on routes operated by Lufthansa and Deutsche BA is higher than on routes operated by Eurowings, with the exception of Frankfurt-Berlin (Statistisches Bundesamt, 1996). Therefore, Deutsche BA can be considered as the most serious competitor of Lufthansa in highly frequented city-pair markets. We already found that the route distance has little influence on fare levels if the route is also operated by a competitor. As a measure against a competitor's entry in an established airline's market, a decrease in fares to oust the new competitor can be expected. As examples the routes Muenchen-Koeln, Muenchen-Berlin, Berlin-Hamburg and Berlin-Duesseldorf have been chosen. In order to compare the results with a route that was under a Lufthansa monopoly (until May 1997), the route Frankfurt-Berlin was chosen. Deutsche BA initiated a new pricing strategy starting from January 20th, 1997, putting Lufthansa under price pressure. Deutsche BA introduced a new fare concept, replacing the former Business-/ Economy class system by a single class system, with a Fully Flexible Fare and two Discount fares (Deutsche BA, 1997c). As reaction on Deutsche BA's simplifying its pricing structure and reducing fares, Lufthansa introduced a new Flexible Economy Fare valid for weekends (Weekend Economy Fare). On all routes with Deutsche BA competition, Lufthansa reduced Discount Economy Fares as well as Business Class Fares, and Fully Flexible Economy Fares, whereas on the Frankfurt-Berlin route these fares remained at their high level, or else increased like the Fully Flexible Economy Fare (Lufthansa 1997c; Deutsche BA, 1996, 1997b). The Lufthansa Pricing Policy only changed drastically since Eurowings entered the Frankfurt-Berlin route in May 1997.

Figure 8: Lufthansa's fare changes on routes with Deutsche BA competition, (DM)



(Lufthansa, 1995; Lufthansa, 1997c; Deutsche BA, 1996; Deutsche BA 1997b)

Lufthansa reacted on new competitive fares by introducing its "Spree-Tarif" on all Berlin-routes, including the Frankfurt-Berlin route in June 1997. Even Deutsche BA was forced to react on this reductions by lowering the "Flexi-Ticket" price on Berlin-routes. Furthermore, in October 1997, Deutsche BA announced the opening of a new route between Muenchen and Frankfurt from November 24th, 1997 with new competitive prices and the introduction of a new "B-Tarif" (like Flexi-Fare, but only available as return ticket). Lufthansa immediately responded, announcing price reductions up to 30% for this route and for the first time Lufthansa fares matched or even undercut Deutsche BA fares (Rodrian, 1997; Lufthansa, 1997e). As a result, Deutsche BA could not gain any market shares and Lufthansa succeeded in ousting the competitor on this route. However, the aggressive fare policy of Lufthansa in this case confirms, that Deutsche BA had successfully taken over market shares from Lufthansa on other routes before.

### 3.2.3.2 Effects of Lufthansa's monopoly loss on the Frankfurt-Berlin route

The effects of pricing competition on Lufthansa and Deutsche BA fares after Eurowings entered the Frankfurt-Berlin city-pair market are shown in table 2. Before Eurowings entered the Frankfurt-Berlin route on May 5th, 1997, Lufthansa's lowest Discount Fare was DM 260, the 7 days Discount Fare was DM 390, the Fully Flexible Economy Fare was DM 780 and the Business Class Fare was 840 DM, and therefore much higher than on the Muenchen-Berlin with Deutsche BA competition. Since the distance on the Frankfurt-Berlin route is even shorter than on the Muenchen-Berlin route, the Federal Anti-Trust Agency (Bundeskartellamt) suspected an improper advantage of Lufthansa's monopoly. Lufthansa explained the discrepancy with high airport charges in Frankfurt and claimed to have losses on all domestic routes, but this explanation was not accepted and in January 1997, the Federal Anti-Trust Agency called Lufthansa to lower fares on this route. "The fare level should be only DM 10 higher than on the Muenchen-Berlin route at a maximum, on which Deutsche BA operates as competitor" (Drucksache 13/7900, 1997).

Table 2: Changes in Lufthansa's fare level under Eurowings competition

	Frankfurt-Berlin May 97		Frankfurt-Berlin June 97		Muenchen-Berlin June 1997	
	466		466		509	
distance (km)						
fares (DM)	Lufthansa	Eurowings <sup>1</sup>	Lufthansa	Eurowings <sup>1</sup>	Lufthansa	Deutsche BA <sup>2</sup>
14 days discount	260	218*	222	198*	222	199
7 days discount	390	458**	333	398**	333	299
Weekend Economy	-	-	420	-	420	-
Spree-Tarif	-	-	470	-	470	-
Fully Flexible Economy	780	638	780	598	560	440/540 (before: 520)
Business	840	798	840	798	590	-

1 Eurowings prices since July 1997; 2 fares since August 15th, 1997; \*just 7 instead of 14 days advance booking rule; \*\*no advance booking rule but other restrictions; Eurowings fares for one way trips, are half the price (Lufthansa, 1997c; Deutsche BA, 1997b; Eurowings, 1997)

Meanwhile, the problem has been resolved by the market entry of Eurowings and the competition between both airlines. The introduction of the "Spree-Tarif" and the Weekend Economy Fare shows the continuous diversification policy in Lufthansa pricing. The introduction of new, less expensive Economy Fares gives a larger choice to customers but makes also the whole fare system more complicated and becomes therefore less user-friendly.

#### 4 RESULTS OF THE ANALYSIS AND OUTLOOK

The EU liberalization policy in air transport markets had a significant influence on the German domestic market replacing a monopolistic market structure by an increasingly competitive structure, with new airlines and more to come, e.g. Virgin Express, Ryanair or Easyjet (Flottau, 1997). Liberalization of the fare system and new entrants helped to reduce Lufthansa's Discount Economy Fares and partly Flexible Economy Fares, but lead also to a more diversified and complex fare system than before. Fare reduction as an effect of competition on most important German routes is a benefit for customers, but the development of a diversified fare system is definitely a drawback. Although Deutsche BA focused on simplifying the fare structure, the company was forced to introduce some special fares on routes to Berlin, due to competition with Lufthansa. This development shows that further diversification and more complex fare systems could become a general problem for all competitors in the market. The comparison of German and Japanese fares has shown that, although the Discount Fares in Germany declined, the Fully Flexible Fares are still high, even in comparison to a less deregulated Japanese fare system. Besides, problems like slot allocation and capacity restrictions of airports, airport charges, air traffic management and governmental subsidies for some national carriers have still to be resolved. The subsidy rule based on the "one-time, but last-time" principle did not lead to an end in subsidizing public airlines. The slot distribution system, based on grandfather rights and the frequent flyer programs, still give Lufthansa quite a strong control over its domestic market and are main barriers for free market development. The European Commission works on initiatives to resolve these problems, but it will still take years to provide better market conditions for airlines in the common market (Kinnock, 1996b). Therefore, it is very unlikely that the introduction of full cabotage will change the German domestic market structure significantly unless the necessary infrastructure and equal opportunities for frequent flyer programs are provided for all airlines (Reuter, 1997a). As market leader, Lufthansa could resist strong competition if the restructuring is successful, but Deutsche BA still has cost and differentiation advantages. However, due to the strong price competition with Lufthansa, the company has not yet been able to announce profits so far and only British Airways can secure the airline's survival. The increasing cooperation between airlines to resist intra-European and international competition is another effect of Europe's open-sky-policy. Airlines will look for more alliances or franchise partners to strengthen their market position. 49 out of 71 worldwide arrangements between airlines in 1995 involved European airlines



(Kinnock, 1996a, 1996b). As a long term effect of liberalization and the markets' limited ability to offer an environment of high competition intensity, a reduction in the number of competitors, by fusion, cooperation between airlines or franchise arrangements, will be observed more often and at the end with just a few competitors dominating the market, fare levels will rise again and could probably even rise to a higher level than ever before.

In Japan, the deregulation continues but still some main topics like the market entries remain controlled. Fare deregulation measures have shown that giving more flexibility in pricing does not necessarily lead to more pricing competition. The difference in fare levels between airlines operating the same route is marginal. If benefits for the customers is one target of deregulation, the Japanese example shows that controlled competition cannot offer the same benefits as a completely deregulated market structure can do. However, the complete deregulation of market entry and fare approval is still to come. Without new competitors in a market, no fare competition will start. The established airlines only have the need to utilize the partly deregulated fare system, if the new airlines entering the market from this year, will start the fare competition. Only with new entrants competing with established airlines for market shares, airlines will use the full range of pricing possibilities. In this situation market leaders will be put under pressure to decide whether to lower prices - or lose customers. However, new airlines have been approved and could change the domestic market starting from 1998, with more competitive fare levels. But like in Europe, the limits to new entries exist, also due to shortage in airport capacities and infrastructure. Unless capacity problems are resolved, the possibilities of competition in the customers' favor will remain limited. Deregulation of air transport markets only has a meaning if all aspects of free market entrance including the improvement of infrastructure and capacity, as well as free pricing are realized in a reform to serve customers better at lower costs - in Europe and Japan.

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**TITLE:** France, Progress of the Interior Laboratory of Aerial Transport.

**ABSTRACT:** After a long period of neglect and waiting which lasted until the bilateral relationship between member states, in the year 1986, there is incontestable progress in the evolution of aerial transport in the European Union. With the signature in February 1986 of the Unique European Act, the beginning of interior progress has been fixed at 31 December 1992. Some weeks much later in April 1986, the Court of European Justice rendered its judgment called "New Frontiers" which stipulated the general rules of relations of Rome, but also their concern with concurrence (Article 85 to 90) as applied to aerial transport.

Thus was completed the final joining of the political agreement and the judicial conditions which allowed preparation of a common aerial transport authority, outlined by the commission in its memorandum of March 1984. The principal support of this policy, the realization of an Interior Department of Aerial Transport was achieved in April 1997 with the establishment of a period of transition and adaptation of about twenty years. The preparations of this work concerned France in two large periods: six years of preparation during of which fixed routes which had been poorly marked were established, (2) the succession of an acceleration phase which imposed, occasionally by radical methods, a complete change in the organization of French Aerial Transport, (3) the multiple consequences imposed on industry, (4) the state, (5) after the laboratory has been established by this process, the French Aerial Transport should progressively insert gradual growth in true transeuropean research.



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**LA FRANCE, LABORATOIRE DU MARCHÉ INTÉRIEUR  
DU TRANSPORT AÉRIEN**

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# 1 INTRODUCTION

Après une longue période d'abstention et d'attentisme, pendant laquelle a perduré le régime des relations bilatérales entre les États membres, l'année 1986 a incontestablement marqué un tournant dans l'évolution du transport aérien au sein de l'Union européenne. Avec la signature en février 1986 de l'Acte Unique Européen l'échéance de mise en place d'un marché intérieur a été fixée au 31 décembre 1992. Quelques semaines plus tard en avril 1986, la Cour de Justice Européenne rendait son arrêt dit "Nouvelles Frontières", qui stipulait que les règles générales du traité de Rome, mais aussi celles concernant la concurrence (art. 85 à 90), s'appliquaient au transport aérien. Ainsi été enfin réunies la volonté politique et les conditions juridiques de base permettant l'élaboration d'une politique communautaire du transport aérien, ébauchée par la commission dans son Mémoire de mars 1984.

Principal pilier de cette politique, la réalisation d'un marché intérieur du transport aérien s'est achevée le 1er avril 1997 à l'issue d'une période de transition et d'adaptation d'une dizaine d'années. Cette mise en œuvre s'est faite en ce qui concerne la France en deux grandes périodes : à six années de préparation au cours desquelles ont été fixées les lignes directrices mais dont les effets ont été peu marqués (2), a succédé une phase d'accélération qui a imposé, de façon parfois radicale, un complet changement dans l'organisation du transport aérien français (3). Les conséquences en ont été multiples tant pour l'industrie (4) que pour l'État (5). Après avoir été le laboratoire de ce processus, le transport aérien français devrait progressivement s'insérer dans un véritable réseau transeuropéen en devenir (6).

## 2 LA PRÉPARATION DU MARCHÉ INTÉRIEUR

A la constance de la politique aéronautique française de 1945 à 1985 (2.1), ont succédé les mesures intermédiaires de la politique commune -premier et deuxième paquets- (2.2), complétées par des décisions anticipatives spécifiques à la France qui ont entraîné les premiers changements dans le ciel français (2.3).

### 2.1 LA POLITIQUE FRANÇAISE DE 1945 À 1985

#### 2.1.1 le partage du ciel

Les circonstances politiques et historiques de l'immédiat après-guerre ont placé le transport aérien français dans un cadre administratif dirigiste et protectionniste, sans que pour autant une politique visionnaire n'ait été élaborée, à l'instar des modes de surface, maritime et ferroviaire. Sur le plan des liaisons internationales régulières, le cadre fixé en 1945 (nationalisation de l'aviation civile) et 1948 (statut d'Air France) se caractérise par un partage du ciel entre la Compagnie Air France et deux compagnies privées (TAI et UAT qui fusionnent en 1963 pour former UTA). Cette situation a perduré jusqu'au rachat d'UTA par Air France. L'attribution des lignes intérieures s'est faite sur une base encore plus rigide puisqu'en 1960 l'État a confié à la société nationale Air Inter l'exclusivité de l'exploitation du réseau national. L'apparition de petites compagnies privées (dites de troisième niveau) n'a

il alors se faire que sur les lignes délaissées par Air Inter, et dans la plupart des cas avec l'aide de la DATAR et des collectivités territoriales.

## **1.2 le service public "à la française"**

Le cadre relativement étroit, ne laissant donc qu'une place très limitée à l'initiative privée, a renforcé la notion de "service public du transport aérien" introduite par une loi de 1932 et maintes fois réexprimée par la jurisprudence. Air France s'est ainsi affirmée dans son rôle de défense du pavillon français à l'extérieur des frontières alors qu'Air Inter s'appuyait sur un système de conventions pour asseoir son monopole sur le transport aérien domestique, les autres compagnies étant soumises à un système contraignant d'autorisations et d'agrément.

Sur le plan économique, ce système de monodésignation d'entreprises en majorité publiques, a été complété par un contrôle administratif des tarifs. Pour sa part, la politique tarifaire d'Air France s'inscrivait naturellement dans le contexte d'entente oligopolistique de l'IATA. Lors qu'Air Inter, incitée par le Gouvernement à défricher de nouvelles lignes au nom de l'aménagement du territoire fut conduit à pratiquer un système de péréquation tarifaire, tout autant plus partiel et imparfait qu'à partir de 1971 Air Inter ne reçut plus aucune subvention publique. Ce n'est que vers 1985 qu'Air Inter mit en place sa tarification tricolore qui eut pour effet d'ouvrir le transport aérien domestique à de nouvelles couches de la population. On put alors parler de début de démocratisation de ce mode de transport.

Le recours au subventionnement a néanmoins largement permis de favoriser dès 1970 le développement des liaisons intraeuropéennes à partir des aéroports de province ; en ce sens Air France se trouvait alors un des précurseurs du développement régional à l'échelle européenne.

## **2 LES ÉTAPES INTERMÉDIAIRES : 1986-1989**

### **2.1 une libéralisation progressive**

Préoccupés de ne pas reproduire le processus rapide de déréglementation aux États-Unis, le Conseil des Ministres de l'Union européenne décida, en 1986, de procéder par étapes pour atteindre l'échéance du 1er janvier 1993 imposée par l'Acte Unique. C'est ainsi que s'instaura une libéralisation progressive, strictement limitée aux liaisons intracommunautaires, qui eut pour effet principal d'assouplir une réglementation rigide -les accords bilatéraux- de façon à accroître la concurrence entre compagnies, tout en harmonisant les règles applicables, notamment sur les plans technique et social. En pratique deux trains de mesure ont été adoptés en 1987 et 1990 avant que ne soit fixé par le "troisième paquet" de 1992 le cadre général du marché intérieur du transport aérien.

### **2.2 les deux premiers paquets**

Respectivement adoptés par le Conseil le 14 décembre 1987 et le 24 juillet 1990, les deux premiers trains de mesure ont très largement assoupli les règles de fonctionnement du marché en ce qui concerne les services entre États membres :

- a) accès au marché : la multidésignation par un État ne peut être refusée par l'autre État concerné si la liaison dépasse un seuil initial de 250 000 passagers par an, ramené progressivement à 100 000 le 1/1/92; la répartition des capacités entre États est élargie jusqu'à 25/75% ; les troisième et quatrième libertés sont généralisées par étapes, avec possibilité d'imposer des obligations de service public ; la capacité en cinquième liberté est portée à 30%, puis 50% du service de base ;
- b) tarifs : le régime reste celui de la double approbation, mais il est créé deux puis trois zones tarifaires (entre 30% et 105% du tarif de référence) à approbation systématique ;
- c) règles de concurrence : sur la base d'une habilitation donnée par le Conseil, la commission a pris en juillet 1988 trois règlements d'exemption concernant respectivement les ententes relatives à la planification, aux horaires, aux capacités, aux consultations tarifaires, au partage des recettes, les systèmes informatisés de réservation, l'assistance aéroportuaire et les consultations sur les trafic de fret.

Le Conseil a également adopté en 1989 un "code de conduite pour les systèmes informatisés de réservation" et en 1991 deux règlements relatifs au refus d'embarquement et aux services de fret, tandis que la Cour de Justice rendait le 11 avril 1989 son arrêt "Ahmed Saeed" imposant aux États d'accroître les libertés en matière tarifaire.

### 2.2.3 des effets restreints

En ce qui concerne le marché français qui a culminé à 7 dont 5 Britanniques, la France n'étant plus en droit de s'opposer à l'exportation de la tradition concurrentielle d'outre Manche. Il en est bien évidemment résulté une augmentation du niveau de compétition pesant sur Air France.

### 2.2.4 l'état du transport aérien français en 1989

Au cours de cette première période, l'incidence des mesures communautaires sur le transport aérien français a été relativement faible : sur le plan formel la commission a été conduite à examiner les accords passés entre AF et IT tandis qu'au plan économique un des éléments les plus significatifs du changement fut l'augmentation du nombre des transporteurs entre Paris et Londres

En 1989, conformément à la politique suivie jusqu'à cette date, le marché français du transport aérien était presque totalement cloisonné, entre régulier et charter, national et international, grands opérateurs (AF et IT), compagnies régionales (TAT et FU) et charters (Minerve, Air Charter et Air Liberté, créée en 1988). Ainsi, malgré les profonds changements qui se faisaient jour dans l'environnement international du transport aérien (redémarrage de la guerre des prix aux États-Unis, grands mouvements de coopération et d'alliances), la France perdurait à l'aube des années quatre-vingt dix dans une situation réglementaire rigide et protectionniste très faiblement nuancée par quelques touches d'un pluralisme bien contrôlé (séries de charters privés en 1987/88 sur Paris/Toulouse, Paris/Bordeaux et Paris/Marseille).

## **2.3 LES MESURES ANTICIPATIVES : 1990-1992**

### 3.1 la constitution du Groupe Air France et ses conditionnalités

Alors que la commission européenne s'apprêtait à instruire une action contre plusieurs États, dont la France, pour qu'ils mettent en pratique le premier paquet, le Gouvernement français annonçait le 12 janvier 1990 l'acquisition d'UTA par Air France qui devenait par voie de conséquence actionnaire majoritaire d'Air Inter. Ainsi 98% des activités de transport régulier se trouvaient concentrés dans la même entreprise, le Groupe Air France. Face à cette situation de quasi monopole la commission, se fondant sur les articles 85 et 86 et le règlement de procédure 3975/87 ouvrait une enquête pour évaluer la conformité de ce regroupement. Les négociations entre la commission, le Gouvernement français et le Groupe Air France aboutirent le 30 octobre 1990, à un accord consacrant le rapprochement entre les trois compagnies mais le soumettant à deux types de conditions :

- i) multidésignation des compagnies françaises sur certaines routes : ouverture à la concurrence franco-française de 61 lignes en quatre vagues successives;
- ii) désengagement du Groupe Air France des compagnies françaises autres qu'UTA et Air Inter et interdiction de toute prise de participation dans le capital d'une compagnie établie en France pendant les 4 ans de la durée de l'accord.

### 3.2 des effets limités

L'accord du 30 octobre 1990 avait celé la fin du monopole total d'Air Inter puisqu'il prévoyait la mise en concurrence des lignes Paris / Ajaccio, Bastia, Bordeaux, Marseille, Montpellier, Strasbourg, Toulouse et Orly / Nice (en lieu et place d'Air France pour cette dernière). Toutefois en traduisant Paris en Charles-de-Gaulle et en limitant le nombre entrants à un seul par ligne, le Gouvernement français restreignit très largement l'effet de la décision de la commission ; fin 1992, Air Inter n'était concurrencée que par TAT sur DG/Marseille et CDG/Toulouse et sur Orly/Nice par AOM qui prit 15% du marché sans entraîner de baisse significative des tarifs. La part prépondérante, l'équilibre et les caractéristiques du monoproduit d'Air Inter n'étaient pas remis en cause (voir BONNET, 1993).

Sur le plan international, la bidésignation n'a pas eu d'effets très significatifs, d'autant plus qu'elle s'est heurtée dans certains cas à l'opposition des pays tiers concernés ou à des difficultés techniques (survol de la Sibérie pour le Paris-Tokyo d'AOM). Finalement sur les lignes susmentionnées, seules 16 ont été exploitées de façon durable.

### 3.3 la première brèche

Malgré ses conséquences réduites, l'accord "Groupe Air France", en permettant à des compagnies privées de créer et d'exploiter des lignes régulières a incontestablement ouvert une brèche dans le monolithisme du paysage aérien français et ainsi préfiguré des changements structurels plus importants, d'autant plus qu'avec ce dossier la commission anticipé les dispositions à venir, de quelques mois pour la multidésignation internationale, et de quelques années pour le cabotage, reporté au troisième paquet.

## **LA MISE AUX NORMES COMMUNAUTAIRES**

Au vu de ce qui précède, on comprend que la France ait eu le souci de ne pas déstabiliser par une libéralisation trop rapide un système très encadré et protectionniste qui avait prouvé son efficacité.

Elle a incontestablement pesé au moment de l'élaboration des règles du jeu définitives en obtenant notamment une période transitoire de longue durée (3.1) ; néanmoins elle a perduré dans une attitude défensive et retardatrice au moment de leur application induisant de nombreux recours et ajustements (3.2).

### **3.1 LE CADRE RÉGLEMENTAIRE**

Le troisième paquet adopté le 23 juillet 1992 consacre la disparition des traités bilatéraux à l'intérieur de l'Union européenne, en affirmant l'autonomie des entreprises soumises à des contraintes résiduelles préservant l'intérêt général.

#### **3.1.1 les règles générales**

La libre prestation de service se manifeste sous le triple aspect des libertés d'établissement, de commerce et de tarifs. Le règlement 2407/92 définit les modalités de délivrance et de renouvellement par un État membre d'une part du certificat d'opérateur qui atteste qu'une entreprise de transport aérien possède les capacités professionnelles et l'organisation pour assurer l'exploitation d'aéronefs en toute sécurité et d'autre part de la licence d'exploitation attestant de la nationalité communautaire de l'entreprise et de sa capacité économique et financière à exploiter son réseau.

Le règlement 2408/92 stipule (art. 3) que tous les transporteurs aériens titulaires d'une licence d'exploitation conforme au précédent règlement « ...sont autorisés par le ou les États membres concernés à exercer des droits de trafic sur des liaisons intracommunautaires ». Cette liberté représente la somme des huit libertés aériennes.

Le règlement 2409/92 marque l'entrée dans le système de la totale liberté tarifaire contrebalancée par des sauvegardes vis-à-vis des tarifs excessivement élevés et des baisses excessives de tarifs. L'application de ces clauses apparaît délicate voire difficile car elles font appel aux notions de pertes généralisées, coûts objectifs à long terme, matching tarifaire dont l'interprétation reste relativement floue.

Les règles de concurrence sont à nouveau adaptées : les exemptions sont reconduites à l'exception du partage des recettes, mais incluent l'exploitation conjointe sur les nouveaux services réguliers de faible densité. L'exemption relative à l'assistance aéroportuaire n'a pu être reconduite au-delà du 1er janvier 1993, compte tenu des conflits d'intérêts entre compagnies aériennes et aéroports, ces derniers faisant l'objet de nombreuses plaintes pour tarifs abusifs. Ce n'est finalement qu'en décembre 1996 qu'un compromis fut trouvé pour une ouverture progressive à la concurrence des services d'assistance, nécessitant la mise en place de procédures de présélection des prestataires de service et d'attribution après appel d'offres.

Le marché libéralisé ne pouvant à coup sûr garantir l'exploitation de liaisons régulières peu rentables nécessitées par la poursuite de politiques d'aménagement du territoire, il convena

alors d'instaurer des obligations de service public, ce que prévoit l'article 4§1 du règlement 2408

Le règlement d'accès aux liaisons contient une clause permettant aux États de restreindre les droits de trafic "s'il existe des problèmes graves de congestion et/ou en matière d'environnement". Cette clause est soumise à des conditions strictes -proportionnalité, neutralité, limitation de durée, publication préalable, contrôle coercitif de la commission ...- qui rendent son utilisation très restrictive.

### **3.1.2 les mesures transitoires**

Le règlement 2408/92 introduit une période de transition pour le cabotage qui, jusqu'au 1er avril 1997, est limité au cabotage consécutif et sous réserve que le transporteur de l'autre État n'utilise pas plus de 50% de la capacité offerte sur le service international. Les États peuvent également pendant cette période continuer à réglementer l'accès à leur marché national. L'article 5 du même règlement permet le maintien des concessions d'exclusivité sur les liaisons intérieures "sur lesquelles d'autres formes de transport ne peuvent assurer un service adéquat et continu", à concurrence de leur échéance ou au plus tard du 1er janvier 1996

## **3.2 L'ÉVOLUTION DES RÈGLES DU MARCHÉ**

L'adaptation de la politique française au nouveau cadre fixé par le troisième paquet s'est faite d'une part par la prise de mesures volontaires, généralement guidée par un souci de préparation de l'industrie, et d'autre part sous la pression de certains acteurs qui, par voix de recours juridiques, ont forcé l'ouverture complète du ciel français.

### **3.2.1 les nouvelles orientations**

Sur le fondement de l'article 3§4 du règlement 2408/92, la France a maintenu sa politique de monodésignation sur les lignes à faible trafic ainsi que l'exclusivité d'Air Inter sur une large partie de son réseau au départ d'Orly.

### **3.2.2 la répartition aéroportuaire corrigée : la décision VIVA AIR**

Se fondant sur l'article 8§1 du règlement d'accès au marché, l'Administration française a maintenu sa tradition interventionniste en matière de répartition aéroportuaire qui conduisait depuis 1974 à une répartition rigide du trafic intracommunautaire entre Orly et Charles-de-Gaulle. Ce comportement a donné lieu à la première décision de la commission prise en application de ce règlement, sur plainte de la compagnie Viva Air à l'encontre de la DGAC. La DGAC a opposé en décembre 1992 un refus à la compagnie espagnole Viva Air, filiale d'Ibéria, d'exploiter la ligne Charles-de-Gaulle/Madrid au motif qu'il était de règle qu'une compagnie ne desserve pas une même liaison à la fois au départ d'Orly et de Charles-de-Gaulle, Ibéria exploitant déjà la ligne Orly/Madrid.

Dans sa décision du 28 mai 1993, la commission a examiné la portée de l'article 8§1 qui permet à un État membre "de réglementer sans discrimination fondée sur la nationalité ou

l'identité du transporteur, la répartition du trafic aéroportuaire entre les aéroports situés à l'intérieur d'un système aéroportuaire." Analysant la "réglementation" française la commission a estimé qu'elle était non transparente (non publication officielle, donc non opposabilité aux tiers), discriminatoire (non application au Groupe Air France qui dessert Madrid à la fois d'Orly et de Charles-de-Gaulle) et non objective (refus contraire à la politique affichée de développement préférentiel de Charles-de-Gaulle par rapport à Orly). Les autorités françaises ont corrigé cette situation par arrêté du 6 décembre 1993.

### 3.2.3 l'ouverture de l'aéroport d'Orly : la première décision "TAT"

Souhaitant profiter des dispositions du règlement d'accès au marché pour développer son activité domestique TAT a demandé le droit d'exploiter la liaison Gatwick/Orly et les liaisons Orly/Marseille et Orly/Toulouse en utilisant les possibilités de cabotage consécutif. Elle s'est vue opposer un refus de la DGAC qui lui a confirmé que la desserte de Londres devait se faire exclusivement à partir de Charles-de-Gaulle.

A l'appui de sa plainte déposée en septembre 1993, TAT soutient notamment qu'il n'y a pas de raison objective à réserver la double desserte Orly & Charles-de-Gaulle aux seules liaisons domestiques, que les règles de répartition ne lui sont pas opposables faute de publication et qu'enfin le refus de la DGAC n'était pas dûment motivé.

La décision 94/290 du 27 avril 1994 est donc intervenue après la publication de l'arrêté du 6 décembre 1993, qui stipulait entre autres que les services aériens à destination ou en provenance de l'Espagne, de la Grèce et du Portugal pouvaient être exploités à partir d'Orly. La commission s'est principalement appuyée sur l'analyse de cet arrêté au regard de la libre prestation de service. Elle a en effet estimé que cet arrêté créait une discrimination, fondée sur la nationalité, au bénéfice des transporteurs français dans la mesure où les transporteurs étrangers n'avaient pas accès à l'essentiel du trafic domestique (par le biais du cabotage consécutif).

Après une bataille avec les autorités britanniques portant à la fois sur les capacités, les fréquences et les créneaux horaires, la France, ne pouvant se prévaloir d'une quelconque réciprocité s'agissant d'une décision relevant du droit communautaire, l'ouverture d'Orly était donc définitivement acquise : trois mois plus tard 5 compagnies avaient ouvert des services entre Orly et Heathrow (BA/TAT, AF et British Midlands), Stanstead (Air UK) ou Gatwick (Air Liberté).

La brèche ouverte pour Londres ne pouvait que s'élargir vers d'autres destinations communautaires. Néanmoins Lufthansa, puis Air France et KLM ont dû saisir la commission devant le refus français d'ouvrir les lignes Orly/Salzburg, Vienne, Francfort et Amsterdam, l'Administration ne prévoyant pas d'ouvrir Orly à d'autres liaisons que Paris/Londres avant le 1er avril 1996. Les autorités françaises ajustèrent à nouveau les modalités d'accès à Orly. Après un nouveau recours de British Airways qui jugeait ces dispositions insuffisantes, la commission par sa décision du 14 mars 1995 consacra l'ouverture totale d'Orly, soumise alors aux seules restrictions relatives aux créneaux horaires.

### 3.2.4 l'ouverture du marché domestique : la deuxième décision "TAT" et sa contestation

En obtenant la période transitoire relative au cabotage et au maintien de la désignation des transporteurs, la France visait implicitement à empêcher l'implantation immédiate de compagnies étrangères par le biais du rachat de petites compagnies locales. La deuxième décision de la commission prononce la main levée de ces dispositions restrictives.

Face au refus du Gouvernement français de l'autoriser à exploiter les lignes Orly/Marseille et Orly/Toulouse, TAT saisit la commission fin 1993. Dans sa décision du 27 avril 1994, la commission a établi qu'il y avait eu discrimination au bénéfice d'Air Inter, dans la mesure où la majorité du trafic Paris/Marseille et Paris/Toulouse passe par Orly qu'Air Inter est seule à desservir ; de ce fait elle interprète ainsi l'exclusivité concédée à Air Inter en une mesure de répartition aéroportuaire, ce qui renforce le fondement de sa décision. Par ailleurs la commission, en limitant la notion d'exclusivité aux liaisons de ville à ville et non d'aéroport à aéroport, ne retient pas l'argument de l'exclusivité concédée à Air Inter, puisqu'en application de l'accord du 30 octobre 1990, TAT avait été désignée sur Charles-de-Gaulle/Marseille et Charles-de-Gaulle/Toulouse, liaisons qui, en outre, constituaient d'autres "formes de transport adéquates", sans compter les transports de surface.

Nonobstant le délai de 6 mois fixé par la commission pour l'application de cette décision, le Gouvernement français, d'une part, a engagé un recours sur le fond devant la Cour de Justice en juillet 1994 et, d'autre part, a saisi en référé le Tribunal de première instance de la Cour pour obtenir le sursis à exécution, arguant du préjudice grave et irréparable que pourraient subir l'organisation du transport aérien français et la politique d'aménagement du territoire. Le juge communautaire a estimé cette hypothèse très imprévisible et rejeté la requête française le 27 octobre 1994, en invitant le Gouvernement à utiliser la législation communautaire relative aux obligations de service public pour maintenir les lignes en cause.

L'ouverture effective de ces deux lignes intervint le 2 janvier 1995. Orly/Marseille voyait ainsi l'arrivée de TAT et AOM tandis que Orly/Toulouse était desservie par TAT et Air Liberté. Cette dernière se lança alors aussitôt dans une guerre tarifaire qu'Air Inter suivit.

### **3.2.5 la gestion des créneaux horaires**

La mise en vigueur du règlement du 18 janvier 1993 a conduit à une remise à plat du système de répartition des "Conférences IATA", basé sur le consensus entre les seules compagnies aériennes. A ce titre les deux aéroports parisiens étaient qualifiés "d'entièrement coordonnés" dès le 10 mars 1993.

Le transfert de l'attribution des créneaux vers la puissance publique ou ses émanations (Aéroports de Paris) ayant été rejeté, la France met en place en août 1995 la structure associative COHOR regroupant exclusivement les principaux utilisateurs, à charge pour ceux-ci d'agir dans la transparence.

S'agissant d'Orly, l'État a fixé à 250 000 le nombre de créneaux horaires délivrables (pour des raisons environnementales), dont une partie réservée aux liaisons d'aménagement du territoire. La situation est bloquée depuis 1996, la totalité des créneaux étant attribués et utilisés.

## **4 LES CONSÉQUENCES SUR L'INDUSTRIE**



L'évolution des règles du marché imposées par la nouvelle loi communautaire s'est traduite par une nécessaire adaptation des compagnies (4.1) tout en permettant de préserver un service public aux contours restreints (4.2). En fin de compte le marché fonctionne malgré quelques excès (4.3).

## **4.1 L'ADAPTATION DES COMPAGNIES**

### **4.1.1 du monopole aux navettes d'Air Inter**

Après l'ouverture à la concurrence de Orly/Bordeaux, Strasbourg puis Montpellier et l'arrivée d'un troisième concurrent sur Nice et prenant acte de la caducité de fait de la Convention Air Inter, le Gouvernement généralisa la multidésignation à partir du 1er janvier 1996. Sur cette base, Air Liberté annonça fin 1995 un programme d'ouverture de 23 lignes tandis que AOM et TAT s'implantaient sur Paris/Toulon, Pau, Perpignan et plusieurs transversales. L'arrivée de la concurrence sur ces nouvelles lignes se fit de façon relativement dynamique sur le plan tarifaire, et joua à plein puisque Air Inter dut céder entre 10 et 40% de parts de marché.

Confronté à cette généralisation de la concurrence et à une première dégradation de ses résultats en 1995, Air Inter, (rebaptisée Air France Europe), annonce au printemps 1996 la mise en place à compter de l'automne suivant d'un système de navettes entre Orly et Toulouse, Marseille et Nice. Ce nouveau produit combine une cadence de vols réduite jusqu'à 30 minutes, une amélioration du service (attribution des places, prestations à bord ...), une plus grande souplesse de réservation et d'embarquement et une gamme tarifaire simplifiée, conservant néanmoins un éventail de 1 à 4.

Cette stratégie a une double conséquence : elle provoque une nouvelle augmentation de l'offre sur les lignes "millionnaires" en termes de capacité et surtout de fréquences mais avec réduction subséquente de la taille des avions.

### **4.1.2 l'implantation des compagnies étrangères**

L'abolition des frontières voulue par la réalisation du marché intérieur conduit tout naturellement à l'implantation de compagnies étrangères dans le ciel français.

Alors que BA/TAT avait utilisé l'argument du cabotage consécutif pour obtenir l'ouverture de l'aéroport d'Orly à toute liaison intracommunautaire internationale, donc l'accès au marché domestique, il apparaît que cette disposition a été très peu utilisée par les autres transporteurs communautaires. Après un épisodique Lisbonne/Bordeaux/Toulouse/Lisbonne par TAP à raison de deux vols hebdomadaires, il faut en effet attendre le 2 janvier 1996 pour qu'Alitalia prolonge ses lignes Rome/Lyon et Milan/Lyon respectivement vers Nantes et Toulouse, avec cabotage sur les segments domestiques. Bien que s'agissant de liaisons de moyenne importance le service proposé par Alitalia remporte un relatif succès. Pour sa part Lufthansa a ouvert début 1997 un service Marseille/Bordeaux en prolongement des ses vols Munich/Marseille. Cette timidité des transporteurs communautaires peut s'expliquer par le coût élevé d'une exploitation à partir d'un aéroport étranger, la difficulté à pénétrer un marché plutôt "nationaliste" et l'inadaptation des flottes. Ceci conforte la stratégie des transporteurs comme British Airways qui ont choisi de s'implanter dans les autres États membres par le biais de l'acquisition d'opérateurs domestiques.

Après le retrait forcé d'Air France et en vue de poursuivre son programme d'extension de lignes européennes TAT a été amené à rechercher un partenaire étranger. British Airways a fait l'acquisition en 1992 de 49% du capital puis des 51% restant en 1995 alors que les résultats s'étaient fortement dégradés. La prise de contrôle par la compagnie Britannique s'est traduite par une réduction de l'effectif et un transfert partiel des activités à Londres. La survie de TAT a conduit sa nouvelle maison-mère à y investir 1,5 milliard de francs entre 1994 et 1996.

Passée de 3 à 18 avions entre 1998 et 1992, Air Liberté, malgré 3 années déficitaires consécutives, s'est lancée dans l'exploitation de lignes domestiques le 2 janvier 1995 en ouvrant Orly/Toulouse. En poursuivant sa double stratégie d'ouverture de lignes et de guerre tarifaire, Air Liberté s'est rapidement retrouvée en difficulté et s'est retrouvée en redressement judiciaire le 26 septembre 1996 alors que le passif atteignait 1,5 milliard de francs. Début 1997, British Airways, allié à la Banque Rivaud, actionnaire et créancier principal, se voyait confier la reprise de la compagnie.

Avec ses deux filiales TAT et Air Liberté (dont la fusion est rendue effective depuis fin 1997), la compagnie britannique détient ainsi 20% des créneaux d'Orly, ce qui renforce considérablement sa position de compétiteur du Groupe Air France sur le marché domestique.

#### **4.1.3 la recomposition du paysage aéronautique français**

La configuration du paysage aéronautique français à la fin de 1996 n'était pas encore stabilisée. Deux dossiers importants restaient à régler, dont l'aboutissement déterminera probablement les rapports de force susceptibles de s'instaurer au sein du marché domestique.

Avec la reprise par le Crédit Lyonnais de ses principaux actionnaires (ALTUS), AOM est devenue filiale à 100% de la Banque publique, puis a été transférée dans sa structure de défaisance, le CDR, en vue de procéder à sa cession aux meilleures conditions. Mais cette opération nécessitait de redresser la compagnie, affaiblie par plusieurs exercices déficitaires dus à une sous-capitalisation caractérisée, aux coûts liés au passage du charter au régulier et à une croissance très rapide. L'approbation par la commission du plan de redressement du Crédit Lyonnais contraint ce dossier dans la mesure où l'actionnaire unique peut difficilement procéder à une augmentation des fonds propres de la compagnie et a fortiori lui permettre d'augmenter son envergure.

Conséquence du refus à la mi 96 des personnels d'Air Inter d'accepter une évolution de leurs conditions sociales permettant de réaliser des gains de productivité comparables à ceux d'Air France, la décision de procéder à la fusion des deux compagnies a été prise début juillet 1996. Elle a ainsi entériné l'abandon de la création d'une compagnie à vocation européenne née du rapprochement d'Air Inter avec le centre de résultats Europe d'Air France. La fusion interviendra effectivement en 1997. Cette fusion devra passer par l'harmonisation des conditions d'emploi des personnels des deux entreprises et le partage et la localisation des activités long et moyen courriers, la privatisation d'Air France devant ensuite intervenir courant 1998.

## **4.2 LA PRÉSERVATION DU SERVICE PUBLIC**

### **4.2.1 une lente mise en place**

L'utilisation de la procédure d'obligations de service public a d'abord concerné les liaisons reliant Strasbourg aux différentes capitales communautaires qu'Air France avait décidé d'abandonner. Mais il aura fallu près de deux ans pour qu'elle aboutisse avec la publication des obligations de service public en octobre 1994.

### **4.2.2 le Fonds de péréquation des transports aériens**

Il est issu des recommandations du Comité "Abraham" institué en décembre 1993 pour analyser l'impact du nouveau cadre réglementaire sur le système de dessertes aériennes domestiques. C'est la loi de finances pour 1995 qui a institué un fonds de péréquation des transports aériens alimenté par une taxe de 4 F perçue dès le 15 janvier 1995 sur chaque passager au départ des aéroports continentaux.

Le fonds fut réglementairement créé par un décret du 9 mai 1995 qui précisa les conditions d'éligibilité des liaisons : lignes intérieures de 10 000 à 150 000 passagers, absence de mode de transport de substitution en moins de 2h30 et absence de liaison alternative sur un aéroport situé à moins de 30 minutes. Le fonds participe à hauteur de 60 ou 80% à la compensation demandée par la compagnie selon qu'il existe ou non une clause tarifaire dans les obligations de service public. L'exclusivité est concédée pour 3 ans.

Si des obligations de service public ont été publiées pour une quarantaine de lignes entre la mi-95 et la mi-96, le recours à l'appel d'offres permettant l'intervention du fonds n'a pas été systématique. En effet plusieurs compagnies, telles que Britair ou Regional, ont préféré accepter de poursuivre sans compensation l'exploitation de lignes qu'elles avaient mis de longs mois à défricher afin de conserver des liaisons s'intégrant rationnellement dans leurs stratégies de réseaux, basés en général sur des "hubs" régionaux tels que Clermont-Ferrand ou Nantes.

### **4.2.3 l'efficacité des procédures**

Ces procédures, bien que relativement lourdes et encore empreintes d'un certain jacobinisme, ont finalement eu le mérite de permettre le maintien d'une desserte cohérente et équilibrée du territoire en assurant le passage d'un système fondé sur le monopole et la péréquation tarifaire interne à celui de la concurrence et de la liberté tarifaire, ajusté par une péréquation externe. Elles préservent donc largement le "service public du transport aérien", là où le tout-marché n'est pas en mesure de répondre (pour une étude approfondie voir Dupéron, 1996 et Grard, 1996).

## **4.3 LE MARCHÉ FONCTIONNE**

### **4.3.1 des effets positifs**

Les effets recherchés par la politique communautaire de libéralisation du transport aérien ont manifestement été atteints en France : l'offre a été largement diversifiée tant en nombre d'opérateurs (jusqu'à 4 sur Orly/Toulouse) et en qualité de service (augmentation spectaculaire des fréquences sur les lignes importantes et amélioration des prestations au sol et à bord) que sur le plan tarifaire avec un élargissement vers le bas qui a permis la conquête de nouvelles clientèles. Il en est résulté, surtout en 1996, des taux de croissance élevés du trafic passager : +15% sur Orly/Toulouse et jusqu'à 80% sur quelques transversales. Globalement le consommateur a incontestablement profité de cette évolution tant en volume qu'en qualité de service.

L'annonce de l'abandon par Air France Europe des lignes Orly/Nantes, Perpignan et Toulon avait suscité de vives réactions de la part des collectivités locales concernées qui en appelaient au maintien du "service public du transport aérien". Malgré la pénurie de créneaux à Orly, la réponse du marché fut immédiate ; la reprise des lignes s'est faite sans discontinuité par TAT et AOM, avec de surcroît hausses de trafic et baisses de tarifs.

#### 4.3.2 d'un excès à l'autre

La guerre tarifaire menée par Air Liberté s'est interrompue avec la mise en redressement de la compagnie. Pour sa part AOM a cessé au bout de quelques mois l'exploitation de Paris/Pau où le potentiel de trafic ne permettait pas à deux opérateurs d'atteindre la rentabilité ; faute d'avoir rapidement dépassé le seuil critique en termes de part de marché, le nouvel entrant a dû se retirer. De même la concurrence entre trois opérateurs sur Orly/Montpellier s'est soldée par le retour au monopole d'Air France Europe malgré plus d'un million de passagers annuels.

#### 4.3.3 vers le duopole ?

Avec le développement de la concurrence intermodale, implicitement encouragée par l'État, la question se pose à présent de savoir si l'ouverture du marché va se poursuivre vers d'autres opérateurs communautaires et dans quelles conditions, ou si plutôt on ne va pas assister à une évolution vers un duopole européen, constitué d'un côté du Groupe Air France et de l'autre de British Airways par TAT et Air Liberté interposées, le rachat par l'un des deux d'AOM (10% des créneaux à Orly) modifiant le rapport de forces ?

L'enjeu de cette vente est la possible constitution d'un hub de British Airways à Orly alors que la stratégie d'Air France est actuellement axée sur Charles-de-Gaulle.

## **5 L'ADAPTATION DU DROIT ET DE LA POLITIQUE AÉRONAUTIQUE**

L'élaboration de la politique commune et sa mise en œuvre ont conduit à réformer les textes et à adapter les structures administratives (5.1) ; elles ont initié une évolution tant du rôle que des pratiques de l'État dont la politique aéronautique est appelée à être réorientée (5.2).

### **5.1 LES EFFETS SUR LES TEXTES ET LES STRUCTURES**

### **5.1.1 l'adaptation du CAC**

Les instruments juridiques qui fixent le cadre final étant quasiment tous des règlements, les seuls problèmes qui se posent étaient des problèmes d'application et non pas de transposition. Néanmoins ce nouveau cadre a conduit à une mise à jour du Code de l'Aviation Civile, dont un certain nombre d'articles étaient devenus obsolètes et qui s'est enrichi d'un troisième volume reprenant intégralement les textes communautaires.

### **5.1.2 le nouveau rôle du CSAM<sup>1</sup>**

S'il conserve ses attributions en ce qui concerne les demandes d'exploitation de liaisons extracommunautaires ou vers les TOM, le CSAM a vu son rôle évoluer pour les liaisons intracommunautaires. En international, il ne lui appartient plus de se prononcer sur l'attribution des lignes puisque leur exploitation est de droit pour toute compagnie communautaire. Par contre en domestique, la politique de limitation du nombre de compagnies par ligne le conduit à proposer des choix d'opérateurs ; avec la suppression de cette restriction en 1996, le rôle du CSAM est à présent dévolu à l'émission d'avis sur la santé économique et financière des compagnies, en regard de la délivrance et du renouvellement des licences d'exploitation prévues par le règlement ad hoc.

## **5.2 L'ÉVOLUTION DU RÔLE ET DES PRATIQUES DE L'ÉTAT**

L'intervention de l'État au cours de cette phase d'adaptation s'est située à tous les niveaux, aussi bien sur le plan régalien pour adapter la réglementation et en surveiller l'application, qu'en tant qu'actionnaire ou tuteur des principaux acteurs (Groupe Air France et Aéroports de Paris). La politique antérieure de maintenir un cadre protectionniste vis-à-vis des sociétés nationales a été totalement remise en cause par le processus de libéralisation ; les changements induits dans le rôle de l'État et les pratiques de son Administration sont en cours de consolidation afin de garantir une application juste, équitable et raisonnable des nouvelles règles du jeu, tout en permettant la poursuite d'une politique desservant des objectifs et intérêts nationaux spécifiques.

### **5.2.1 la séparation des rôles**

Dans un premier temps la privatisation du Groupe Air France, envisagée pour 1998 et la vente d'AOM conduiront au désengagement de l'État en tant qu'actionnaire, condition sine qua non pour garantir une totale neutralité vis-à-vis de l'industrie. Ultérieurement la création de structures dédiées pour le contrôle de la circulation aérienne, la formation aéronautique et le contrôle technique des aéronefs en isolant les fonctions d'opérateurs devrait permettre d'améliorer l'identification et l'exercice des fonctions régaliennes.

<sup>1</sup> Le Conseil Supérieur de l'Aviation Marchande est un organisme consultatif placé auprès du ministre des Transports. Composé de représentants de la profession, de l'Administration et des Collectivités territoriales, il est principalement chargé de donner des avis sur les créations de compagnies et l'ouverture des lignes.

### 5.2.2 la garantie de l'application des règles communautaires

Elle conduit à adopter une attitude de surveillance et d'arbitrage fondée sur la mise en œuvre de critères neutres, transparents et non discriminatoires face à un nombre indéterminé d'agents économiques.

La question des créneaux aéroportuaires implique doublement l'État. D'une part il lui appartient de fixer la capacité des aéroports saturés en harmonie avec les normes communément admises et en fonction, le cas échéant, d'une politique objective de limitation pour motifs environnementaux. D'autre part, même si leur répartition vient d'être confiée aux opérateurs eux-mêmes, l'État devra veiller à leur correcte utilisation par les compagnies en instaurant au besoin un système de sanctions ou de pénalités.

Sur le plan des tarifs, bien que la démarche soit délicate et complexe l'élaboration de critères d'excès est nécessaire pour contenir les comportements prédateurs des opérateurs ; pour garantir la pérennité de l'industrie française, notamment en regard d'objectifs sociaux, l'État pourrait faire une utilisation judicieuse du règlement relatif aux licences d'exploitation.

### 5.2.3 la politique aéronautique en devenir

L'un des piliers de la politique communautaire du transport aérien est la mise en place d'un marché intérieur où les lois de la concurrence s'exercent librement. Les États ne peuvent plus y déroger depuis le 1er avril 1997. Néanmoins, et le cadre communautaire le permet, ils peuvent apporter les ajustements voulus là où le "tout-marché" ne répond pas. En ce sens, la France peut poursuivre sa politique d'aménagement du territoire, même si la notion de service public a été fortement restreinte et encadrée.

L'amorce de la décentralisation de la politique aéronautique via les lignes à obligations de service public devrait pouvoir s'étendre au développement des liaisons interrégionales européennes que les collectivités territoriales appellent de leurs vœux. Une extension du Fonds de péréquation des transports aériens pourrait probablement satisfaire cette demande. Face à une augmentation de la demande née de la reprise économique ou liée aux stratégies de réseaux en étoiles des compagnies, la priorité consiste plutôt à présent à assurer la croissance des capacités de l'espace aérien et des aéroports, ce qui au demeurant constitue une des façons de soutenir l'industrie nationale face à la concurrence intra et extracommunautaire.

## **3 DU MARCHÉ AU RÉSEAU**

La réalisation d'un marché intérieur du transport aérien dont on peut dire que la France a été le laboratoire (6.1) doit être replacée à travers les autres composantes de la politique communautaire du transport aérien dans la perspective de la construction d'un réseau paneuropéen (6.2).

### **5.1 LE LABORATOIRE DU MARCHÉ**

#### 5.1.1 la singularité française

L'évolution du transport aérien français se singularise notablement au sein de la communauté en ce sens qu'aucun autre État membre n'a connu pareils bouleversements tant dans l'adaptation de sa politique que dans la structure de son industrie ; l'examen des décisions de la commission et des arrêts de la Cour de Justice, hormis celles concernant les aides d'États, montre que la France a monopolisé les contentieux dans la mise en œuvre du marché intérieur du transport aérien.

### **6.1.2 les processus**

Alors qu'elle avait pu négocier des conditions permettant de préparer son industrie, la France a finalement dû mettre en place le cadre de la libre prestation de service sous la contrainte réglementaire ou jurisprudentielle des instances communautaires : deux années de bataille juridique ont ainsi conduit à l'ouverture complète du ciel. Outre ce volet principal, pratiquement tous les autres aspects du marché intérieur du transport aérien ont donné lieu à actions, contestations et corrections : répartition aéroportuaire, créneaux horaires, obligations de service public, concentrations et aides d'État. Sur le plan formel, la France s'est donc bien transformée en véritable laboratoire.

### **6.1.3 les effets**

La mise en œuvre du marché intérieur du transport aérien en France a incontestablement entraîné, par le biais des bas tarifs, une augmentation significative du nombre de passagers domestiques ; ceux-ci ont pu faire jouer la concurrence sur les principales lignes, non seulement au plan tarifaire mais également en terme de qualité de service ; les consommateurs ont donc globalement profité du nouveau cadre réglementaire.

Par contre les conditions de guère tarifaire dans lesquelles s'est faite l'ouverture du ciel domestique ont eu des conséquences néfastes sur l'industrie française : en 1996, toutes les compagnies régulières sont déficitaires et l'une d'entre elles est passée dans le giron d'une compagnie étrangère. Il n'est donc pas exclu que les réajustements tarifaires auxquels elles seront inévitablement conduites réduisent dans un proche avenir la forte croissance constatée en 1995/1996.

Sur le plan environnemental la libéralisation a entraîné une forte multiplication des fréquences, supérieure à celle des passagers ; l'augmentation des mouvements qui en est résulté sur les aéroports parisiens contribue à l'accélération de leur saturation et exacerbe la sensibilité des riverains. Cette évolution a d'ores et déjà eu des répercussions sur le calendrier de développement de l'aéroport Charles-de-Gaulle, confronté plus tôt que prévu à des problèmes de saturation, eux-mêmes susceptibles de contraindre Air France dans sa stratégie de hub et d'alliances transatlantiques.

Les grands aéroports de province, qui ont largement ressenti les effets de la libéralisation, à la fois au plan domestique mais également au plan intracommunautaire, s'engagent pour la plupart vers l'anticipation ou l'accélération de leurs programmes de développement des infrastructures terminales.

## **6.2 VERS UN RÉSEAU TRANSEUROPEEN**

Le Traité de Maastricht a fixé comme objectif la mise en œuvre des réseaux transeuropéens de télécommunications, d'énergie et de transport. Une décision conjointe du Parlement et du Conseil a arrêté le 23 juillet 1996 les orientations communautaires pour le développement du réseau transeuropéen de transport. Outre les objectifs, les priorités ainsi que grandes lignes d'action, cette décision identifie les projets d'intérêt commun dont la réalisation doit contribuer au développement du réseau.

La mise en place du cadre légal définitif du marché intérieur du transport aérien constituait la première étape de la construction de ce réseau. Néanmoins ce marché ne deviendra une pleine réalité économique que :

- d'une part lorsque l'on considérera que le transport aérien est une industrie comme les autres, même si elle se particularise par de fortes spécificités (capitalisation élevée pour des rentabilités faibles, caractère hautement international et grande élasticité au PNB ...) et ne peut que très partiellement relever de l'approche "service public" ;
- d'autre part lorsque seront réduites, en Europe, les contraintes dues aux infrastructures, aéroports et espace aérien, de façon à ce que les compagnies accroissent leur efficacité et leur compétitivité ; c'est l'un des objectifs de la décision sur les réseaux.

Du fait de sa situation géographique, la France est plus particulièrement concernée par la question de l'espace aérien qui, au demeurant, dépasse le cadre communautaire et met en jeu d'autres organisations internationales spécialisées telles que la CEAC et Eurocontrol. Par sa forte implication dans les processus d'harmonisation et d'intégration de la navigation aérienne en Europe, la France joue pleinement son rôle dans ce domaine. L'industrie française du transport aérien, outre l'achèvement de son redressement devra donc également se préparer à prendre une place de référence dans un réseau dont le caractère multimodal est appelé à se concrétiser.

## 7 CONCLUSION

Malgré les réticences opposées par la plupart des partenaires des États-Unis à l'exportation de sa politique de déréglementation, et malgré les chocs pétroliers qui avaient quelque peu freiné sa croissance, le transport aérien mondial a connu une forte reprise au cours des années 80 qui a conduit les États dotés d'une aviation commerciale développée à s'orienter vers un assouplissement du carcan juridique de la Convention de Chicago.

La France n'a pas échappé à cette tendance mais il aura fallu la mise en vigueur de la politique communautaire de libéralisation et notamment son troisième paquet de mesures, pour précipiter son changement d'attitude ; finalement, elle a été conduite à reproduire en trois ans l'évolution des 8 à 10 premières années de la déréglementation américaine et à placer momentanément son industrie du transport aérien dans une situation relativement fragilisée.

Mais si l'on dépasse le débat doctrinaire sur la libéralisation et ses effets négatifs primaires et que l'on veuille bien considérer que cette marche forcée vers un réseau transeuropéen consolidé a pour objectif le renforcement des capacités de l'industrie européenne du transport aérien à affronter la concurrence américaine et asiatique, il importe alors que tous les acteurs -État et compagnies- continuent à intégrer l'évolution communautaire dans leurs pratiques et stratégies pour garantir le maintien d'une place honorable au "pavillon national".



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**AIR TRAVEL DEMAND PROJECTIONS THROUGH 2010:  
THE CASE STUDY OF ISTANBUL ATATÜRK AIRPORT**

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## **1 INTRODUCTION**

This study evaluates the current traffic capacity of Istanbul Atatürk Airport in order to investigate the possibility of an increase in efficiency and to specify the need for a second airport in Istanbul. The research is based on traffic demand projections (passenger, aircraft, and cargo) for the Atatürk Airport until 2010. Initially, regression models are separately developed for international and domestic passenger traffic, cargo traffic, and aircraft traffic. Subsequently, in order to make reliable projections until 2010, four different scenarios are developed. Scenario I is based on trend analysis while the others assume that variables will show fluctuations similar to previous years' but with different rates. Scenario II represents the status quo while Scenario III and IV represents the optimistic and pessimistic cases respectively. All the scenarios reveal that the Atatürk Airport urgently needs supplementary terminal buildings and runways, and that a second airport in Istanbul is indispensable.

## **2 PASSENGER TRAFFIC**

### **2.1 International lines**

#### **2.1.1 Forecasting model**

In order to develop a regression model which will reflect the international passenger traffic of the Atatürk Airport most appropriately, the data concerning the international traffic (both for arriving and departing passengers) for the January 1986-May 1996 period are collected and analysed. The trend in the data shows a sharp decline in February 1991 due to the Gulf crisis. However, the period before and after 1991 shows a different pattern. i.e. the general trend before and after this period is not the same. Based on the widely held opinions concerning the variable with the greatest influence on passenger traffic, the OECD Countries' Industrial Production Indexes (IPI) and Turkey's Industrial Production Indexes (TIPI) are used as the basic indicators of the world income for the same period and are included in the research (Horonjeff and McKelyev, 1994; Tessun, 1997; OECD Statistical Yearbooks; SPO Monthly Statistics Bulletins). One of the reasons for choosing Industrial Production Indexes as an indicator of the Gross National Income is that, while the Gross National Income is declared every three months, this research uses monthly periods. Furthermore, in the developed countries, the industrial and service sector income represents 80-90% of the total income, whereas the agricultural income is only 5-10%. Due to the high level of correlation between the industrial and service sector income, the industry index is accepted to be a good indicator of income.

During the estimation phase, the E-view software package is used. The best-fitted equation obtained for the international passenger traffic is given in Table 1:

Table 1. International passenger traffic forecasting equation

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>T-Statistic</i>	<i>Prob.</i>
C	-2.4537	2.4157	-1.0157	0.3126
LIPI	3.1232	0.5587	5.5898	0.0000
LTIPI	0.0211	0.1443	0.1465	0.8839
D91	0.3241	0.0629	5.1573	0.0000
DD91	-0.3068	0.0763	-4.0201	0.0001
M	0.0637	0.0331	1.9252	0.0576
M(-1)	-0.0235	0.0468	-0.5016	0.6172
M(-2)	-0.1921	0.0566	-3.3987	0.0010
M(-3)	-0.0196	0.0582	-0.3373	0.7367
M(-4)	0.1522	0.0646	2.3561	0.0208
M(-5)	0.2214	0.0640	3.4610	0.0008
M(-6)	0.2874	0.0651	4.4153	0.0000
M(-7)	0.5357	0.0610	8.7783	0.0000
M(-8)	0.6801	0.0563	12.0783	0.0000
M(-9)	0.4487	0.0485	9.2442	0.0000
M(-10)	0.3078	0.0356	8.6396	0.0000
MA(1)	0.8331	0.1043	7.9873	0.0000
MA(2)	0.5611	0.1319	4.2537	0.0001
MA(3)	0.4051	0.1330	3.0457	0.0031
MA(4)	0.3407	0.1059	3.2164	0.0018
R-squared	0.9610	Mean dependent var		12.8044
Adjusted R-squared	0.9522	S.D. dependent var		0.4196
S.E. of regression	0.0917	Akaike info criterion		-4.6086
Sum squared resid	0.7149	Schwartz criterion		-4.1031
Log likelihood	112.9640	F-statistic		110.0966
Durbin-Watson stat	1.9783	Prob(F-statistic)		0.0000
Inverted MA Roots	.23-.70i	.23+.70i	-.65+.46i	-.65-.46i

In this equation, in order to linearize the non-linear structure of the OECD Countries' and Turkey's income level, the logarithms of the corresponding data is taken (LIPI and LTIPI respectively). The elasticity corresponding to those variables is found by using logarithms. For example, the coefficient of LIPI shows that a 1% increase corresponding to the OECD Countries' income level will result in a 3.1232% increase in the international passenger traffic. The *t* values are used to test whether the coefficient of a variable is equal to zero or not. When the *t* value is closer to "2" in absolute term, it can be said that the coefficient is not equal to "0" for 5% significance level. If the coefficient is equal to "0", the corresponding variable does not have any explanatory power. It can be deduced from the *t* values given at the table (0.146470) that Turkey's income level does not have a significant impact on the international passenger traffic.

D91 and DD91 are two dummy variables that reflect the crisis situations. DD91 is described in such a way that it takes the value "1" for the 2<sup>nd</sup> month of 1991 and "0" for the other months. Similarly, in order to reflect the difference between the periods before and after 1991, the dummy variable D91 takes the value "1" and "0" respectively.

In the regression model (1), seasonal variables reflect seasonal variations. In this model, when November is taken as the month on the basis of which the comparisons are made, M reflects the relative situation for December; M(-1) for January, M(-2) for February and so on. According to the seasonal variations, there is a significant increase in passenger traffic in April (M(-4)), May (M(-5)), June (M(-6)), July (M(-7)), August (M(-8)), September (M(-9)) and October (M(-10)), compared to November. On the other hand, in February

(M(-2)), a significant decrease with respect to November can be observed. Since the t values of the corresponding variables are both greater than "2", the confidence level is greater than 95%.

Finally, the variables with the abbreviation "MA", show the autocorrelation, i.e. the correlation between the standard error of one period with that of the previous one.

### **2.1.2 Scenario analysis approach for international passenger traffic projections**

According to the regression equation built by using past data, the variable with the greatest impact on international traffic is LIPI. Although its coefficient and t values are very small, in order not to avoid the impact of the domestic market, LTIPI is considered as the second explanatory variable. The other factors reflect the seasonal variations. It is clear that an accurate projection for the international passenger traffic until 2010 is totally dependent on making accurate projections for LIPI and LTIPI. However, due to the highly dynamic nature of these two variables and their volatile structure, it is not adequate to make long term projections using traditional quantitative techniques.

The forecasting techniques, known as "quantitative" or "technological" techniques are generally used for long-term forecasting purposes. In quantitative forecasting techniques the general principle is to assume that the future will be similar to the past. Although this principle is useful for a short period, when the forecasting involves medium to long term periods, it becomes more and more difficult to accept. The quantitative forecasting techniques do not reflect the world's dynamism. Their projections are obtained solely by analysing the relation between the variables using the past data and assuming that those relations will stay the same in the future.

In technological forecasting, on the other hand, the creative power and knowledge of the experts play an important role in reaching accurate predictions. In technological estimations, there is no deterministic information about the iterations to be adopted step by step and the estimations obtained are not given as single values.

In this study, the projections of LIPI and LTIPI are obtained through scenario analysis which is a popular technological forecasting technique. Four different scenarios are developed in order to investigate the possible trend in the domestic and foreign income levels until 2010. Subsequently, the values obtained for LIPI and LTIPI from each of the four scenario analyses are placed in the regression model explained in section 2.1.1. MA's are not taken into consideration during the projections. When the characteristics of the data are investigated, it is revealed that, for the 1986-1996 period the growth of LIPI and the income trend show a fluctuating pattern. The average growth per month in 1986-96 is 0.001584. This growth is 0.003286 for 1986-90, -0.000198 for 1990-94 and 0.002573 for 1994-1996. Furthermore, for the period 1986-96, LTIPI shows seasonal fluctuations and contrary to LIPI, it does not have different fluctuation patterns for different intervals.

The first of the four scenarios is based on trend analysis and called Scenario I. In this scenario, the explanatory variables (LTIPI and LIPI) are used to explain the estimated number of international passengers. It is known that the trend estimations are obtained by discarding the fluctuations that exist in the data. However, as mentioned above, when the

past data concerning LIPI was analysed, a 4-year fluctuation pattern was found. That is why, in the other scenarios it is assumed that this variable will show fluctuations similar to those that appeared in the past. As a result the Status Quo Scenario (Scenario II), the Optimistic Scenario (Scenario III), and the Pessimistic Scenario (Scenario IV) are developed. The details of the scenarios are explained below.

■ SCENARIO I:

This scenario can be called "Based on Trends (Growth Without Fluctuation)" Scenario. Since Turkey's income does not fluctuate, its average growth rate is accepted to be 0.004313. It is assumed that world income will show a growth of 0.001584 per month, without any fluctuations. Based on this scenario, the projections until 2010 are calculated. The results are as follows: There is a continuous growth in the monthly values based on yearly values compared with 1996, the peak month's estimations of international passenger traffic increase by 35% in 2001 and reach 1,731,985. In 2010, the estimations reach 2,984,267 with an increase of 133%.

■ SCENARIO II:

When the historical data is analysed, fluctuations at 4-year intervals can be observed in LIPI. Scenario II is based on the assumption that this pattern will continue in the future. It is accepted that a growth similar to that of 1994-96 (0.002573) will be seen again in 1996-98. However, there will be a decrease by 0.000198 in the 1998-2002 period, an increase by 0.002573 in 2002-2006 and finally a decrease by 0.000198 in 2006-2010. It is also assumed that LTIPI will continue to show the trend-based pattern, similar to the past data and that its monthly growth rate will be 0.004493. Therefore, this second scenario can be called "The Status Quo" Scenario. The projections of LIPI and LTIPI are obtained and put in the LINTPAS regression equation. The corresponding projections till 2010 show that the highest values are reached in August and the second highest are in July. The projected values for the peak month international passenger traffic reflect the fluctuations seen in the past. The peak month passenger number increases until 1998 reaching 1,488,977. Then, it decreases to 1,461,175. The fluctuation reaches 2,145,156 at 2006 and continues with a decrease down to 2,091,919 at 2010. Based on these forecasts it can be said that, compared to 1996, the peak month international passenger traffic will increase by 11% in 2001 and by 59% in 2010.

■ SCENARIO III:

In this "Optimistic" Scenario, it is assumed that LTIPI will exceed the average growth rate of 0.004493 by one standard error (i.e. there will be a growth of 0.004673). On the other hand, LIPI will have a decrease of 0.00198 during the recession periods and the increase, however, will be similar to that of 1986-1990 period and will, thus, be equal to 0.003286. When the corresponding projections based on these assumptions are investigated, a fluctuation is observed. The peak month passenger number increases to 1,571,620 in 1998 and decreases to 1,547,487 in 2001. Similarly, the fluctuation continues and the estimated values become 2,520,548 in 2006 and 2,459,964 in 2010. Compared to 1996, there is a 15% increase in 2001 and a 84% increase in 2010.

■ SCENARIO IV:

The last scenario, where all the explanatory variables show an inconvenient pattern can also be called the "Pessimistic" Scenario. In this scenario LIPI shows a growth equal to

one half of the past average growth rate of 0.001584. TIPI is assumed to be one standard error below the average growth rate. Accordingly, the projections obtained are relatively greater than those obtained in the third scenario. In August, which is the peak month for 2001, the international passenger traffic will increase by 16% compared to 1996 and become 1,453,450. In 2010, on the other hand, the relative increase will be 51% and the traffic will reach the level of 1,895,656. As a result, the passenger traffic values will be below those of the other scenarios.

### **2.1.3 The evaluation of the international passenger traffic**

The current capacity of the terminals for international passengers is 8.5 million passengers/year. 5 million passengers/year of this capacity is utilized by the international passenger terminal while 3.5 million/year of it corresponds to the charter terminal. However, the international passenger traffic estimation for 1996 is 10,178,568 passengers/year for the Optimistic Scenario, and even for the Pessimistic Scenario it reaches 9,630,614 passengers/year. It is obvious that the current capacity cannot satisfy the demand level even for the pessimistic scenario. Due to the fact that the terminal buildings work beyond their capacities, the service quality is in decline. There are frequent problems in queues and luggage collection areas. Additional terminal buildings are urgently needed. If the additional building capacity is planned to be 5 million passengers/year, as it is in the current situation, the total capacity will reach a level of 13.5 million passengers/year. However, if Scenario I becomes a reality even this new capacity will be exceeded. For the other scenarios, capacity will be exceeded in the years 2004, 2003 and 2008 respectively. On the other hand, if the new terminal is planned to have 10 million passengers/year, the total capacity will be 18.5 million passengers/year. This capacity will also be exceeded in 2007 according to Scenario I and in 2005 according to Scenario III. Based on the international passenger traffic estimation of Scenario II and IV, however, even in 2010 it will not be possible to reach this capacity level. Figure 1 shows all these estimations in detail.

## **2.2 Domestic lines**

### **2.2.1 Forecasting model**

The forecasting model which reflects the domestic lines passenger traffic most accurately, has a structure similar to that of the international lines. This structure also shows differences for periods before and after 1991. On the other hand, while the international passenger traffic shows a decline in the second month of 1991 due to the Gulf crisis, in the domestic lines, this decline is in the fourth month due to a strike in the period of April 1-May 9, 1991.

The best-fitted forecasting equation, which is developed for domestic lines passengers is given in Table 2. In this equation, LDOMPAS is the logarithm of the number of domestic lines passengers using Atatürk Airport in a month. One of the most important explanatory variables is LTIPI. The coefficient of LTIPI is 0.6919. This shows that an increase of 1% in Turkey's income will result in an increase of 0.6919% in the domestic passenger traffic.

Figure 1. International passenger traffic estimations

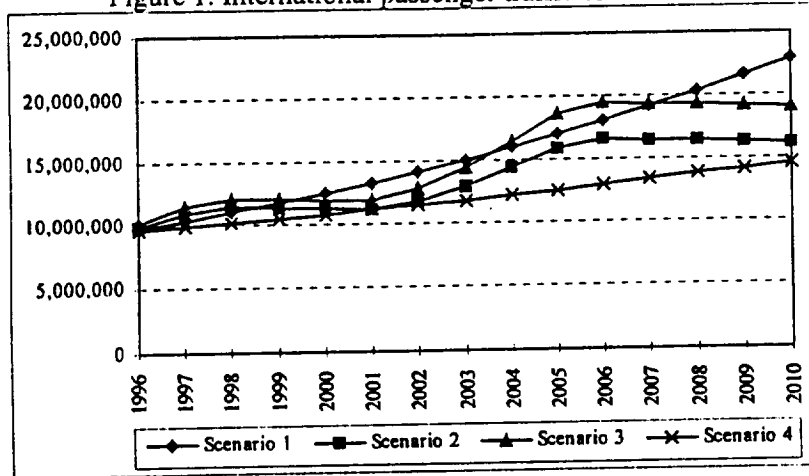


Table 2. Domestic passenger traffic forecasting equation

Variable	Coefficient	Std. Error	T-Statistic	Prob.
C	3.7770	0.8972	4.2098	0.0001
LTIPI	0.6919	0.1348	5.1336	0.0000
LDOMPAS(-1)	0.3806	0.0365	10.4158	0.0000
D914	-1.4203	0.0444	-32.0109	0.0000
D91	-12.3883	3.0161	-4.1075	0.0001
D91LPI	2.6118	0.6347	4.1248	0.0001
M	0.0340	0.0383	1.0378	0.3024
M(-1)	0.0659	0.0431	1.5292	0.1300
M(-2)	0.0669	0.0492	1.3580	0.1781
M(-3)	0.1016	0.0484	2.1004	0.0387
M(-4)	0.2657	0.0420	6.3291	0.0000
M(-5)	0.3064	0.0504	6.0755	0.0000
M(-6)	0.2991	0.0408	7.3274	0.0000
M(-7)	0.3102	0.0441	7.0258	0.0000
M(-8)	0.3988	0.0436	9.1386	0.0000
M(-9)	0.2304	0.0374	6.1531	0.0000
M(-10)	0.1205	0.0395	3.0500	0.0031
MA(1)	0.3190	0.0807	3.9514	0.0002
MA(2)	0.4186	0.0841	4.9806	0.0000
MA(3)	0.0901	0.0776	1.1617	0.2486
MA(5)	0.7006	0.0828	8.4566	0.0000
R-squared	0.9703	Mean dependent var		12.0571
Adjusted R-squared	0.9632	S.D. dependent var		0.3794
S.E. of regression	0.0727	Akaike info criterion		-5.0648
Sum squared resid	0.4445	Schwartz criterion		-4.5340
Log likelihood	137.9153	F-statistic		137.2622
Durbin-Watson stat	1.7134	Prob(F-statistic)		0.0000
Inverted MA Roots	.62+.59i	.62-.59i	-.32-.97i	-.32+.97i
	-.93			

Furthermore, in domestic passenger traffic, contrary to the structure of international lines, the demand pattern shows a dynamic property that is dependent on the previous year's demand level. For any given year, the domestic lines passenger traffic is found to be dependent on the previous year's traffic (LDOMPAS(-1)).



The differences for the period before and after 1991 are taken into account by using two dummy variables: D91 ("1" for the years 1991 and after, and "0" o/w), D914 ("1" in the 4th month and "0" o/w). LIPI begins to influence the domestic lines passenger traffic in 1991. This is shown by the dummy variable D91 (D91LIPI). Due to the fact that the t values of all those explanatory variables are much greater than 2, they have a significance level greater than 95%.

Like the forecasting model of international passenger traffic, the seasonal fluctuations (M's) and the previous month's standard error terms (MA's) are found significant and, thus, taken into account.

### **2.2.2 Scenario analysis approach for domestic passenger traffic projections**

Similarly to the scenarios generated for the traffic projections of international lines, four scenarios are developed to estimate the passenger traffic of domestic lines.

#### **■ SCENARIO I**

In this scenario, which can be defined as "Based on Trends", the assumptions are similar to those given for international lines and the same necessary computations are repeated in order to get LDOMPAS values until the year 2010. When the values are analysed, it can be seen that the domestic line passenger traffic projections show a pattern without fluctuations. According to Scenario I, the peak month passenger number will increase 6 fold with respect to 1996 and reach 2,862,773. This is the highest level of all the Scenarios.

#### **■ SCENARIO II**

Scenario II has the same assumptions as international lines. The projections of LIPI and LTIPI obtained for international lines are copied exactly to make the projections of the domestic lines, and they are used to get the projected values for LDOMPAS. On the other hand, the coefficient of "C" is corrected in such a way as to reflect seasonal fluctuations and the decline of the 4<sup>th</sup> month. When the monthly projections until 2010 are analysed, it can be emphasized that in the 8<sup>th</sup> month, the traffic reaches its peak level, as was the case for international lines. Furthermore, when a yearly evaluation is made, a continuous increase can be seen in the number of passengers. For example, in the year 2000, the peak month domestic passenger traffic increases by 49% with respect to 1996 and reaches the level of 746,602. In 2005, these values are 217% and 2,163,325 respectively.

#### **■ SCENARIO III**

The "Optimistic" Scenario developed for international lines is the same for the domestic lines. In LDOMPAS equation, the optimistic projections obtained for LTIPI and LIPI are taken into account and the coefficient of C is corrected in such a way as to take into account the fluctuations and declines that occurred in respective months, in order to get the projections for the domestic passenger traffic until 2010. When these projections are analysed, it can be seen that the peak month domestic passenger traffic will be 831,399 in 2000, 2,048,491 in 2005, and 2,854,281 in 2010. The projected increases for 2000, 2005 and 2010 are 1.6, 3.9 and these are 5.4 times the 1996 values.

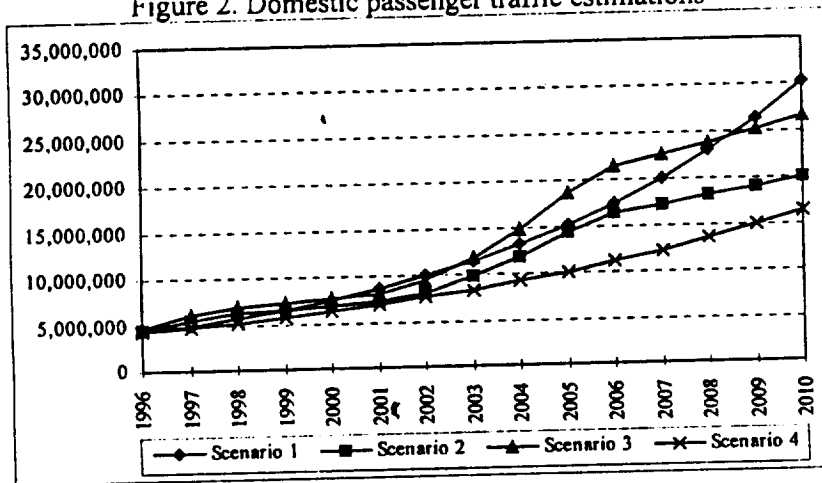
▪ SCENARIO IV

This scenario which was called “Pessimistic” in the international lines is also applied to the domestic lines. The revealed projections show that, the passenger traffic estimations are below those of the other scenarios. Accordingly, the peak month domestic line passenger traffic will be 680,672 in 2000, 1,101,481 in 2005 and 1,782,444 in 2010. The increase in 2010 is 285% with respect to 1996.

**2.2.3. The evaluation of domestic lines passenger traffic**

The capacity of the terminal building used for domestic lines is 2 million passengers per year. On the other hand, the domestic line passenger traffic is estimated to be 4,805,999 passengers/year for 1996 and even in the “Pessimistic” Scenario, it is 4,281,830 passengers/year. This shows that, in its current level, the capacity of the terminal building is not enough even to satisfy the demand of 1996. An additional capacity is urgently needed. If an additional capacity of 5 million passengers/year is found to be appropriate for the first stage, the total capacity will increase to 7.5 million passengers/year. This capacity will be satisfactory until 2000 for Scenario III, and until 2002 for Scenario IV. If an additional capacity of 10 million passengers/year is accepted, however, the total capacity will increase to 12.5 million/year and this will be exceeded in 2004 under the “Optimistic” Scenario and in 2008 under the “Pessimistic” Scenario. The details of those evaluations can be seen in Figure 2.

Figure 2. Domestic passenger traffic estimations



### 3 THE CARGO TRAFFIC

#### 3.1 Forecasting model

Since the data about the cargo traffic in the period 1986-1996 at the Atatürk Airport could only be found in the form of *total* arrivals and departures for the *total* of domestic and international lines, it is not possible to prepare evaluations for domestic and international lines separately. A significant drop in the cargo traffic is seen in the 1986-1996 period because of the Gulf Crisis in 1991. Depending on this finding, the forecasts done by using the E-View software package. A dummy variable D914 is defined by assigning 1 for the decrease on the fourth month of 1991 and 0 for the rest of the months.

The coefficients of variables LTIPI and LIPI are different before and after 1991. In other words, while the coefficients of LTIPI and LIPI are 0.4119 and 2.0598 respectively before 1991; after 1991, 0.7736 is added to the coefficient of LTIPI (D91LTIPI) and -0.8058 is added to the coefficient of LIPI (D91LIPI). On the other hand, the cargo traffic presents a dynamic structure and is found to be effected by the traffic of the previous period. Additionally, on the 12<sup>th</sup> month, a meaningful correlation with the previous month (MA12) is revealed. The seasonal fluctuations of cargo traffic are not significant. The resulting equation is given in Table 3.

#### 3.2 Scenario analysis approach for cargo traffic projections

When the forecasting equation for cargo traffic is analysed, LTIPI and LIPI are seen as the main explanatory variables. Therefore, for these two variables, the projections that are done separately in four scenarios for passenger traffic projection, are fully adopted for the cargo traffic. The following scenario findings have been reached.

Table 3. Cargo traffic forecasting equation

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>T-Statistic</i>	<i>Prob.</i>
C	-5.2845	1.985	-2.6623	0.0090
LIPI	0.4119	0.1732	2.3776	0.0192
LTIPI	2.0598	0.5525	3.7283	0.0003
D89	-0.6643	0.0718	-9.2567	0.0000
D914	-0.6733	0.1093	-6.1586	0.0000
LCARGO(-1)	0.3201	0.0654	4.8962	0.0000
D91LIPI	0.7736	0.3150	2.4558	0.0157
D91LTIPI	-0.8058	0.3377	-2.3861	0.0188
MA(12)	0.3777	0.1009	3.7447	0.0003
R-squared	0.8744	Mean dependent var		9.0059
Adjusted R-squared	0.8648	S.D. dependent var		0.3133
S.E. of regression	0.1152	Akaike info criterion		-4.2468
Sum squared resid	1.3931	Schwartz criterion		-4.0308
Log likelihood	89.3068	F-statistic		91.3454
Durbin-Watson stat	1.8354	Prob(F-statistic)		0.0000
Inverted MA Roots	.89-.24i	.89+.24i	.65+.65i	.65+.65i
	.24+.89i	.24-.89i	-.24-.89i	-.24+.89i
	-.65+.65i	-.65-.65i	-.89+.24i	-.89-.24i

#### ■ SCENARIO I

The cargo projections are calculated until 2010 according to the assumptions of "Based On Trends (Growth Without Fluctuations)" Scenario (see subsection 2.1.2). When the projection values are examined, it can be seen that, unlike the passenger forecasts, August is not the peak month and there is no seasonal fluctuation. The December values are the highest of the year and the forecast value for the cargo traffic is increasing yearly. If the expected increase takes place, the forecast value of cargo traffic for the peak month will be 24,400 tons in 2000, 45,655 tons in 2005 and 85,420 tons in 2010. For these three years the increase ratios with respect to 1996 are 65%, 209% and 478% respectively.

#### ■ SCENARIO II

When the LIPI and LTUPI projections done in the "Status Quo" Scenario are put in the LCARGO equation and the necessary corrections for the determined months are made, the projected cargo traffic values can be reached in the year 2010. Based on these values, it can be forecast that the cargo traffic for the peak month will be 23,998 tons in 2000, 47,894 tons in 2005 and 75,149 tons in 2010. For these years the ratios of increase with respect to 1996 are 53%, 204% and 478% respectively.

#### ■ SCENARIO III

The cargo projections until 2010 under the assumptions of the "Optimistic" Scenario are the highest forecast cargo traffic values. On the peak month, 24,400 tons of cargo will be carried in the year 2000 and 45,655 tons will be carried in 2005. In the year 2010, the peak month value will be 90,788 tons. For these years, the ratios of increase in relation to 1996 are 57%, 241% and 445% respectively.

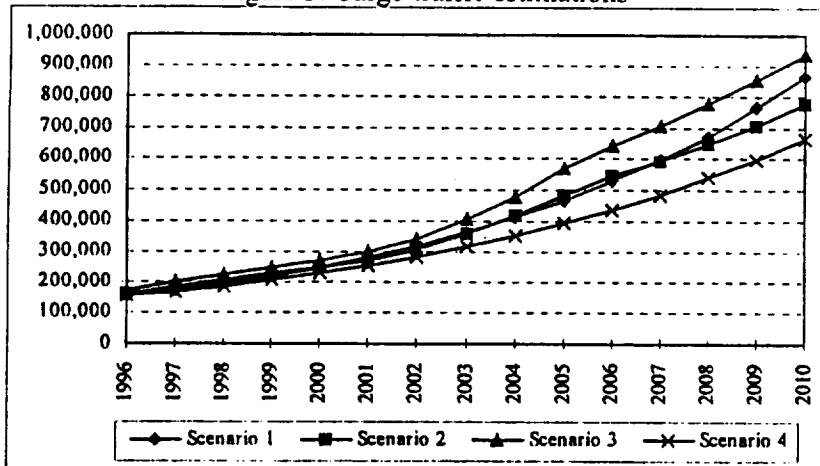
#### ■ SCENARIO IV

When the cargo projections until 2010 under the assumptions of the "Pessimistic" Scenario, (for which the external factors showed negative progress) are examined, it can be seen that the forecast values in this scenario are less than the other scenarios. The peak month values are 22,287 tons for the year 2000, 38,057 tons for 2005 and 64,987 tons for 2010. For these years the ratios of increase in relation to 1996 are 53%, 162% and 347% respectively.

### 3.3 The evaluation of cargo traffic

The evaluations of the scenarios can be seen on Figure 3. We can see that the level of cargo traffic will be 250,000 tons in the year 2000. According to the "Status Quo Scenario, on the other hand, 500,000 tons in 2006 and 750,000 tons in 2010 will be exceeded. According to the "Optimistic" Scenario, the level of 250,000 tons in 2000, 500,000 tons in 2005 and 750,000 tons in 2008 will be exceeded. According to the "Based on Trends" Scenario; the level of 250,000 tons, 500,000 tons and 750,000 tons in 2000, 2006 and 2009 respectively will be exceeded. Finally, according to the "Pessimistic" Scenario the level of 250,000 tons will be exceeded in 2001. Since the increase in the cargo traffic is less in this scenario, the level of 500,000 tons will be exceeded in 2008.

Figure 3. Cargo traffic estimations



## 4 THE AIRCRAFT TRAFFIC

### 4.1 Forecasting model

#### 4.1.1 Forecasting model using a variable that is stable around the mean

In order to develop a model for forecasting aircraft traffic, initially, the "number of passengers per number of aircraft" (PPA) is investigated. This is calculated by dividing the number of passengers who used the Atatürk Airport during the 1986-1996 period, by the number of aircraft that used the same airport at the same interval. During that time period, PPA is found to be stable around the mean. In other words, the mean of the PPA variable does not vary in a statistically significant way. On the other hand, by analysing the autocorrelation, the existence of a seasonal variation is observed: PPA increases and decreases at certain months of the year.

Based on these findings, developing a forecasting model with a stable variable around the mean is considered appropriate. In this model, the PPA of the previous month, a constant, and an artificial variable ( $M(-1)$ ,  $M(-2)$ ,... etc.) representing each month are used. The forecasting model is given in Table 4.

When the forecast parameters are examined, it is observed that the PPA increases in the summer months. By using this forecasting model, PPA is forecasted till 2010.

In the second phase, in order to obtain the estimated number of aircraft that used the Atatürk Airport, the projection of the number of passengers based on the scenario analysis of the previous models is used. Accordingly, the number of aircraft that made international flights (INTAIR) is forecast by dividing Scenario I, II, III, and IV values concerning the projection of the number of international passengers by PPA and the number of aircraft made domestic flights (DOMAIR) is forecast by dividing Scenario I, II, III, and IV values concerning the projection of number of domestic passengers by PPA.

Table 4. PPA traffic forecasting equation

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>T-Statistic</i>	<i>Prob.</i>
C	12.8039	4.9796	2.5713	0.0116
M	4.2588	1.9146	2.2244	0.0283
M(-1)	4.6981	1.9143	2.4542	0.0158
M(-2)	3.7341	1.9084	1.9566	0.0532
M(-3)	3.1244	1.9166	1.6302	0.1062
M(-4)	5.5269	1.9327	2.85697	0.0052
M(-5)	4.1587	1.9711	2.1098	0.0374
M(-6)	9.2283	1.9706	4.6830	0.0000
M(-7)	8.1419	1.9285	4.2220	0.0001
M(-8)	14.2967	1.9304	7.4060	0.0000
M(-9)	3.6879	2.0363	1.8111	0.0731
M(-10)	2.5713	1.9590	1.3126	0.1923
PPA(-1)	0.7413	0.0671	11.0549	0.0000
R-squared	0.7418	Mean dependent var		69.3384
Adjusted R-squared	0.7111	S.D. dependent var		7.8040
S.E. of regression	4.1944	Akaike info criterion		2.9745
Sum squared resid	1776.903	Schwartz criterion		3.2865
Log likelihood	-318.3054	F-statistic		24.1815
Durbin-Watson stat	2.2452	Prob(F-statistic)		0.0000

When these estimated values of aircraft traffic are examined, it can be seen that the fluctuation of the projection of number of international passengers (an increase for 1996-1998, a decrease for 1998-2002, an increase for 2002-2006, and a decrease for 2006-2010) will lead to fluctuations in the number of aircraft used for international flights. As there is no fluctuation in the number of domestic passengers, there is a continuous increase in the total number of aircraft. However, the slope of this increase is higher when there is an increase in the number of international passengers. Additionally, as the number of aircraft is dependent on passenger traffic, there are seasonal variations in the total number of aircraft as well. It is forecast that this number will be highest in August. According to the scenarios, in the peak month of 2010, the estimated total number of aircraft will be 76,772, 52,904, 65,058, and 45,028 aircraft respectively. The rates of increase of those values in relation to the values of 1996 are 260%, 140%, 188% and 116% respectively.

#### 4.1.2 Forecasting model using a linearly increasing variable

When technological developments and the increase in the demand for aircraft traffic are taken into consideration, planes with higher seating capacities are expected to be constructed in the future. In accordance with this expectation, in order to develop projections for the number of aircraft, it is suitable to include an additional forecasting model with a linearly increasing variable in addition to the forecasting model with stable variable around the mean (section 4.1.1) Accordingly, two different analyses are obtained and evaluated.

- The linear increase model dependent on total passenger traffic:

Initially, the monthly average of "linearly increasing number of passengers per number of aircraft" (LIPPA) for 1996 which is 71.76, is forecast to become approximately 100 in the year 2010. In this case, each year, the LIPPA value is expected to increase by 2. By using LIPPA values and total number of passenger projections until 2010, an estimation of the total (domestic and international flights) number of aircraft is obtained. According to the scenarios, the aircraft traffic projections for the month of August will be 56,796, 38,539, 48,130, and 33,312 aircraft in 2010. In relation to the 1996 values, the increase is 166%, 74%, 112%, and 60% for each scenario respectively.

- The linear increase model for international and domestic passenger traffic:

In order to construct a detailed design, models considering international and domestic passenger traffic separately are also analysed, besides using the linear increase model which considers total passenger traffic. Accordingly, 70 aircraft (the number of passengers per domestic aircraft for 1996) is accepted to be approximately 100 for 2010. Then, the projection of domestic aircraft is obtained until 2010. The number of passengers per number of international aircraft for 1996 which is 80 is accepted to increase linearly and reach 125 for 2010. Again, the projection of international aircraft is obtained until 2010. According to the estimated values of both domestic and international aircraft traffic, the domestic aircraft traffic projection values for August in 2010 will be 29,768, 19,953, 25,851, and 16,143 aircraft in each scenario respectively. For the same month of the same year, the international aircraft traffic projection values will be 22,202, 15,563, 18,301, and 14,103 aircraft.

#### **4.2 The evaluation of aircraft traffic**

The capacity of the Atatürk Airport is presented as 350,400 aircraft/year (SPC Airway Transportation Commission Report, 1995; SAGM Statistical Yearbook, 1995). This is a theoretical capacity which can not be realised in a safe, comfortable and healthy environment. This capacity value is calculated by assuming that both runways are used every three minutes for 24 hours a day.

The evaluation of aircraft traffic according to PPA is given in Figure 4. In Figure 4, it can be seen that the estimated aircraft traffic values of the scenarios exceed the level of 350,400 aircraft/year in 2003, 2004, 2003, and 2007 respectively.

The evaluation of aircraft traffic according to LIPPA is given in Figure 5. It can be seen that estimated aircraft traffic values of the first three scenarios exceed the level of 350,400 aircraft/year in 2005, 2006, and 2004 respectively.

Accordingly, the runways will exceed their theoretical maximum capacity in a short period. As there is no additional space for building a new runway around the Atatürk Airport, a new airport should be constructed in a different area in or around Istanbul.

Figure 4. Aircraft traffic estimations according to PPA

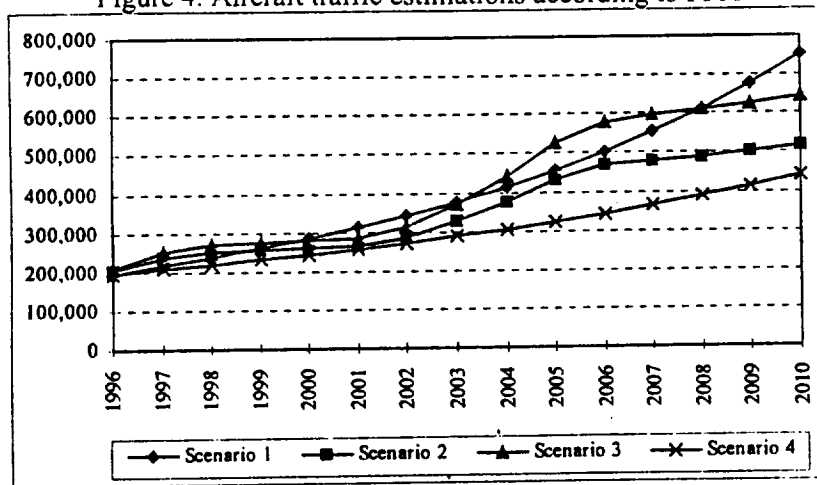
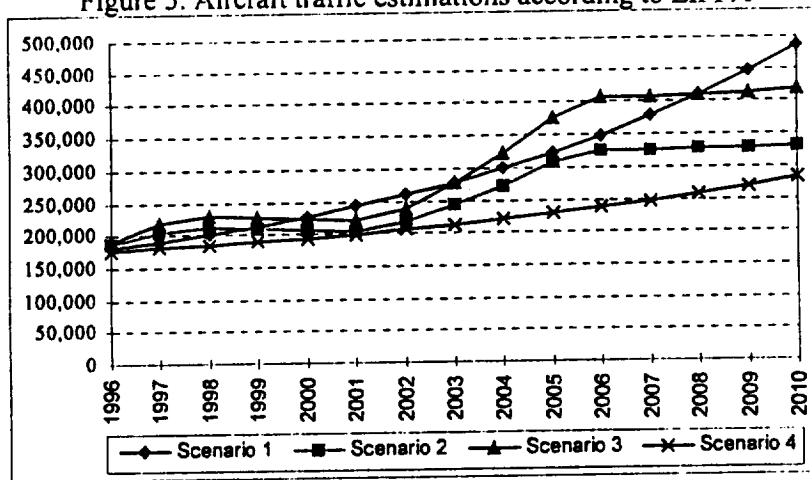


Figure 5. Aircraft traffic estimations according to LIPPA



### 4.3 Average peak hour demand estimation

#### 4.3.1 Average peak hour demand estimation dependent on total passenger traffic

As mentioned above, all forecasting equations and projections are calculated in a monthly basis (the given annual passenger, cargo, and aircraft traffic projection values are obtained by summation of monthly values). However, as the peak hour and peak day capacity of the airport is in question, the peak demand should be calculated in order to determine the requirements of an airport design. A method suggested at the Airport Planning Manual (1987) is used for this calculation. The method is as follows:

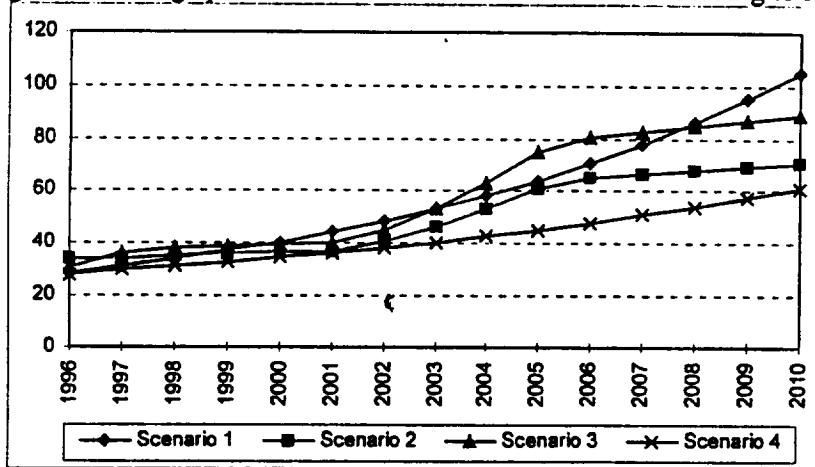
1. Peak hour/peak day average ratio (peak hour traffic rate) is obtained using data from the previous year
2. The traffic values of the two peak months are determined for each projection year



3. For these two peak months, the number of "average" passengers using the airport is calculated. Here, the "average" day is assumed to be the 30<sup>th</sup> or 40<sup>th</sup> busy day of the year and can be called a typical peak day.
4. The typical peak hour passenger traffic is calculated by using the peak hour traffic rate and the typical peak day.
5. Average peak day aircraft traffic is calculated by dividing typical peak day passenger traffic by PPA and LIPPA
6. Average peak hour aircraft traffic is calculated by dividing average peak day aircraft traffic by 24

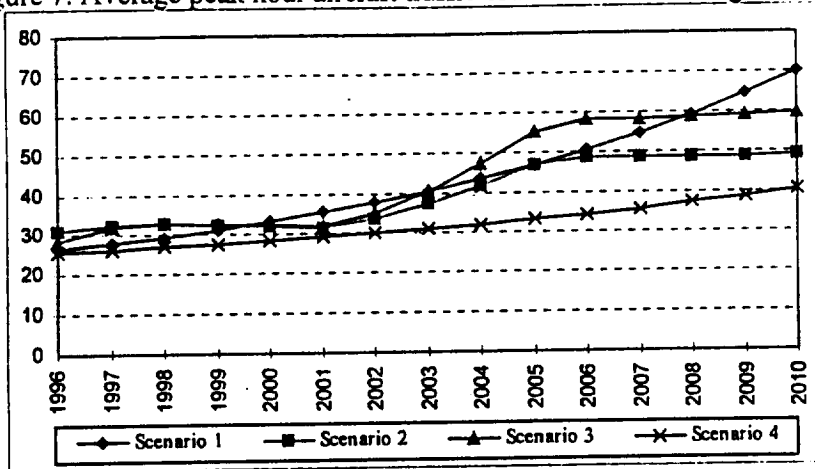
As shown in Figure 6, the average peak hour aircraft forecast values dependent on PPA will be 29 aircraft in 1996, 41 aircraft in 2000, 64 aircraft in 2005, and 105 aircraft in 2010 according to the first scenario. According to the second scenario, the estimated values of 1996, 2000, 2005, and 2010 will be 34, 37, 61, and 71 aircraft respectively. According to the third scenario the estimated values of the same years are 31, 40, 75 and 89 aircraft respectively. As the average peak hour aircraft traffic is dependent on the passenger traffic, an increase in the average peak hour aircraft traffic in the years when there is a increase in the projection of the number of international passengers is higher than the increase in the average peak hour aircraft traffic in the years when there is a decrease at the projection of the number of international passengers. In Scenarios II and III, there is a higher increase in the estimated values for the period 2000 and 2005. According to the fourth scenario the estimated values of the years mentioned above are 28, 35, 46, and 62. Peak hour aircraft traffic in 1995 was 37 aircraft (March 2, 15:00-16:00). The average peak hour aircraft projection values exceed this level in 1999, 2001, 2000, and 2002 according to each scenario.

Figure 6. Average peak hour aircraft traffic estimations according to PPA



According to the first scenario, the average peak hour aircraft forecast values dependent on LIPPA will be 29 aircraft in 1996, 37 aircraft in 2000, 52 aircraft in 2005, and 77 aircraft in 2010. According to the second scenario the estimated values of 1996, 2000, 2005, and 2010 will be 34, 33, 49, and 52 aircraft respectively. The estimated values of the same years according to the third scenario are 31, 36, 60, 65 aircraft and according to the fourth scenario they are 28, 31, 37, 45 aircraft respectively. Values in the scenarios exceeds the level of 37 aircraft in 2001, 2003, 2002, and 2006 (Figure 7).

Figure 7. Average peak hour aircraft traffic estimations according to LIPPA



#### 4.3.2 Average Peak Hour Demand Estimation Dependent on Domestic and International Passenger Traffic

In order to construct a detailed design, in addition to the average peak hour demand estimation dependent on total passenger traffic, the average peak hour demand estimation dependent on domestic and international passenger traffic should be analysed. The method is the same as in section 4.3.1. The only difference is in the use of domestic and international passenger projections instead of the total passenger projections and in obtaining average peak hour domestic and international aircraft traffic forecast values instead of average peak hour total aircraft traffic forecast values.

### 5 THE EVOLUTION OF THE FORECASTING EQUATIONS

The selection of the most accurate forecasting equations is a difficult process. The most suitable equations were obtained after several trials with the explanatory variables that are stated as “significant” in the literature (Oakervee, 1994; Airport Planning Manual, 1987; Horonjeff & McKelvey, 1994). The “insignificant” variables are not included in these equations. They are as follows;

- **Tourism income:**

Since the data used is from the post-1988 period and the airports used for tourism purposes, like Dalaman, were already in use during this period, the tourism income could not affect the forecasting equation of the international passenger traffic in Istanbul Atatürk Airport. On the other hand, the equation used in this research includes variables representing seasonal variations and, thus, implicitly take tourism into consideration.

- **Price changes:**

It is well known that the income elasticity of luxurious products is high and their price elasticity is low. The “price changes” variable included in the models developed in this research is found insignificant. This may be explained by the fact that air travel is

considered as "luxurious" in our country. This is not the case in developed countries. On the other hand, since the price changes have an increase pattern similar to that of the inflation rate, the impact of these changes are partly seen through the trend of the income level.

■ Information about socio-demographic structure and income distribution:  
The data related to this information is not available for Istanbul in the monthly and even yearly basis. therefore, it is not included in the equations.

■ Population:  
This variable is also found insignificant because during the forecasting period of 1986-1995 only two censuses were held (in 1985 and 1990). As a result, it would have been necessary to make an interpolation between these two values in order to obtain the population corresponding to other years. Additionally, although monthly data is used in the forecasting equations developed in this research, monthly variations in population are not available.

## 6. RESULTS

For each scenario analysis, projections concerning international passengers, domestic passengers, cargo, and aircraft traffic are obtained. In order to utilise these results and obtain "the most likely" values that can be taken as a basis for various future designs, the average of minimum and maximum forecast values is taken. The average of the values in Scenario I and IV for international passengers, domestic passengers, and aircraft traffic and the average of the values in Scenario I and III for cargo traffic are computed and presented in Table 5.

Table 5. The most possible projection values that can be used for evaluation

YEAR	ANNUAL				AVE. PEAK HOUR		
	International passengers	Domestic Passengers	Cargo ton	Aircraft (PPA)	Aircraft (LIPPA)	Aircraft (PPA)	Aircraft (LIPPA)
1996	9,716,566	4,328,602	156,226	194,255	177,923	28	26
1997	10,166,243	4,864,840	176,922	212,764	184,647	30	27
1998	10,639,275	5,474,586	199,831	228,263	192,232	33	28
1999	11,136,977	6,163,450	222,406	245,101	200,692	35	29
2000	11,660,744	6,942,018	247,599	263,580	210,105	38	31
2001	12,212,050	7,822,332	275,734	283,894	220,559	40	32
2002	12,792,461	8,818,090	312,047	306,262	232,156	43	34
2003	13,403,631	9,944,882	358,187	330,929	245,009	47	36
2004	14,047,316	11,220,455	411,235	358,171	259,247	51	38
2005	14,725,375	12,665,014	472,218	388,303	275,018	55	40
2006	15,439,779	14,301,574	533,400	421,680	292,484	59	42
2007	16,192,614	16,156,356	593,872	458,704	311,833	64	45
2008	16,986,095	18,259,239	661,379	499,831	333,273	70	48
2009	17,822,566	20,644,280	736,794	545,580	357,040	76	52
2010	18,704,512	23,350,312	821,069	596,537	383,399	83	55

According to projection values in the near future, .

- the current capacities of international and domestic terminals will not satisfy the projected demand of international and domestic passengers. Either these buildings should be extended or new terminal buildings should be constructed.
- the theoretical capacities of two runways of the Atatürk Airport will not satisfy the aircraft demand of aircraft. This will result in congestion. A new runway should be constructed. Since there is no additional space for constructing a new runway around the Atatürk Airport, a new airport should be constructed in a different area in or around Istanbul.

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**„A Hands-On Analysis of the Future Framework  
of the European Airline Industry  
Using a Software-Assisted Scenario-Methodology“**

Written by:

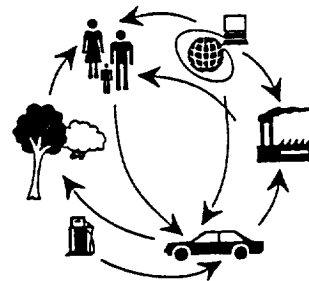
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## 1 STATUS QUO & MOTIVATION

Presently, the European airline industry features some ambivalent characteristics. On the one hand side its passenger numbers as well as its freight tonnage show strong signs of growth, on the other hand side the industry is confronted with a difficult situation, i.e. burdened with infrastructural shortcomings and uncertainties, e.g. with respect to what will happen after the 3<sup>rd</sup> liberalisation package has come into effect. Moreover, some airlines already have or are in the midst of undergoing comprehensive restructuring and privatisation, whilst others remain in their respective state's hands yet and/ or are heavily subsidised. This plus the ongoing economic work sharing worldwide, high growth rates in tourism and their influence on aviation necessitate a deeper understanding of and insight into the dependencies of the air transport system.

Whereas the airline analyst can assume that most European airlines have already made and are implementing the planning and strategic decisions covering the near future, the more distant future implies more scope of action and thus more uncertainty of what business ideas should be realised and what strategies applied and when.

Also, the airline strategist is only partly aware of what prospective activities are pursued by the airline's competitors. Furthermore, technological „quantum leaps“ do not follow deterministic patterns and thus are very difficult to predict.

Strategic decisions with regard to greater investments or the implementation of far-reaching strategies focused on various business units (i.e. their market behaviour) require an extensive outlook into the farer future. This is imperative for an early identification of relevant developments (early warning) and the realisation of their consequences on the industry as a whole, so as to maintain an airline's competitive advantage over its competitors. For this scenarios suggest themselves. Applied to the underlying topic, they serve as a first step to assess the potential of yet-to-be finalised developments within the European airline industry.

The aim of the scenario process conducted here is to provide decision-makers in the airline industry, air transport analysts and personnel of state authorities and of other institutions involved with possible, conceivable and consistent future perspectives regarding the European air transport industry. This knowledge will enable all the interested parties to subject their objectives and actions to an examination of costs and benefits, help to avoid or make use of specific risks and chances and to maintain or better their place in the top league.

The application of the scenario-methodology to the problem field mentioned above and illustrated in this paper<sup>1</sup> was realised by collaborating with other experts (both scientists and practitioners) from all over the aviation field, following the process in figure 1. The aim was to reach as good an understanding of the European airline industry now and in the future as was possible in the given time frame<sup>2</sup>.

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<sup>1</sup> This represents part of the results of the first module of Mr Dussoye's PhD thesis, named 'A Scenario-Based Analysis of the Future Framework of the European Airline Industry & Derivation of Strategies for EU-Airlines' at Berlin University of Technology's (TU-B's) Aeronautical Department, Section Flight Guidance and Control/ Air Transportation, which was methodically supported by Daimler Benz' 'Society and Technology Research Group'.

<sup>2</sup> Based on the empirical knowledge of the respective experts deduced during the scenario process, Mr Dussoye's PhD thesis will focus on modeling part of the industry sector and on

Figure 1: Schedule of Activities towards the Scenario-Workshop

Timeline

Authors	Group of Experts	
FIRST INVESTIGATIONS due to existing problems when accessing specific information on the airline industry, COMMENCEMENT of DATA RETRIEVAL.	SEARCH FOR EXPERTS interested in the matter.	18.3.97
CONFIGURATION: ↳ Planning and design of contents, form and duration of the questioning process, preparation and organisation of the questionnaire. ↳ Formation of group of experts (among other things request and motivation to participate).	FIRST NOTIFICATION of potential experts.	24.6.97
	CONFIRMATION of 32 (out of 42) EXPERTS willing to participate	25.9.97
1. SURVEY ( <i>Uncertainty-Impact-Analysis</i> ): TASK: Appraisal of main relevant pressures from the authors' open primary list with regard to their future importance and their future uncertainty (see section 2.4).		
	ANSWERS from 32 participants	22.10.97
PROCESSING OF INFORMATION: ↳ Feedback: Statistical group results of appraisal and visualisation in diagramme format. ↳ Proposition of 18 pivotal influencing factors (number due to software limitations) for further study by a core team of 14 experts. ↳ Classification of identified pivotal influences into premises and descriptors and derivation of their state (now and in the future) plus derivation of accompanying a-priori-probabilities.		21.11.97
2. SURVEY: TASK: Request for comments on proposed pivotal influencing factors, on their classification into premises/ descriptors, on their current and future state and regarding their a-priori-probabilities.		28.11.97
	COMMENTS	
ANALYSIS: ↳ Confirmation or revision of proposals made by the core team.		
PREPARATION OF THE WORKSHOP: Feedback: ↳ Visualisation of results ↳ Completion of descriptor essays ↳ Provision of workshop participants with complete set of necessary information material.		
	INFORMATION OF workshop PARTICIPANTS	10.12.97
CONDUCT OF THE INTERACTIVE SCENARIO-WORKSHOP	9 PARTICIPATING EXPERTS	11.12.97

deriving exemplary future airline strategies from a yet to be developed decision support system. For this he will further make extensive use of primary research, i.e. include experts from the outset in order to avoid results purely developed in the 'scientific ivory tower'.



## 2 METHODOLOGY AND RESULTS – STEP BY STEP

### 2.1 Introduction

Assuming the above mentioned status quo - i.e. the necessity of making decisions with far-reaching implications and to some degree under uncertainty regarding the development of important environmental factors - scenario techniques<sup>3</sup> represent a pragmatic approach to reduce the vagueness and to help systematise it, so that the resulting measures remain transparent, reconstructable, plausible and above all purposeful. For this, the following steps have to be taken (general approach):

### 2.2 Step 1 - The Topic

**Define and structure the topic/ problem area as precisely as possible and give it an acceptable and understandable formulation.**

For the underlying topic this resulted in formulating the following question:  
 „What are the main relevant pressures or influencing factors for analysing the future framework of the European airline industry?“

In order to keep the problem area easy to grasp and to derive the most appropriate answers, the following limitations were introduced:

- Thematic focus:** structure and organisation of the airline industry, this being the thematic focus of Mr Dusoye's PhD research;
- Geographical focus:** airlines, having their main spheres of activity within the EU, s.a.;
- Timely focus:** long-term, i.e. for the time interval 'today ⇨ 2015', in compliance with today's long-term forecasts, e.g. Boeing's Current Market Outlook or Airbus' Global Market Forecast.

### 2.3 Step 2 - Influencing Factors

**Identify the main areas of influence with regard to the problem area and collect and (where necessary) reduce and cluster the influencing factors which describe part or whole of the mentioned areas of influence.**

Commencing with an open and extendable primary list of 76 main relevant influences or pressures on the European air transport sector prepared by the authors of this study<sup>4</sup> and

<sup>3</sup> The main objective of the scenario-building process is to systematise complex problem settings very briefly, to analyse the underlying influences and their interdependencies and to reflect and visualise their future impact on product and/ or service needs. Final outcome is the creation of distinctive future worlds, the description of how these have developed from the present situation and an analysis of why these specific future worlds are more probable than others.

<sup>4</sup> Making extensive use of on-line data retrievals at Berlin University of Technology (e.g. by utilising ILR's own and the MBA department's online databanks), at the EU, at the ESA etc, by searching the world wide web and the internet for all relevant information, gathering bits and

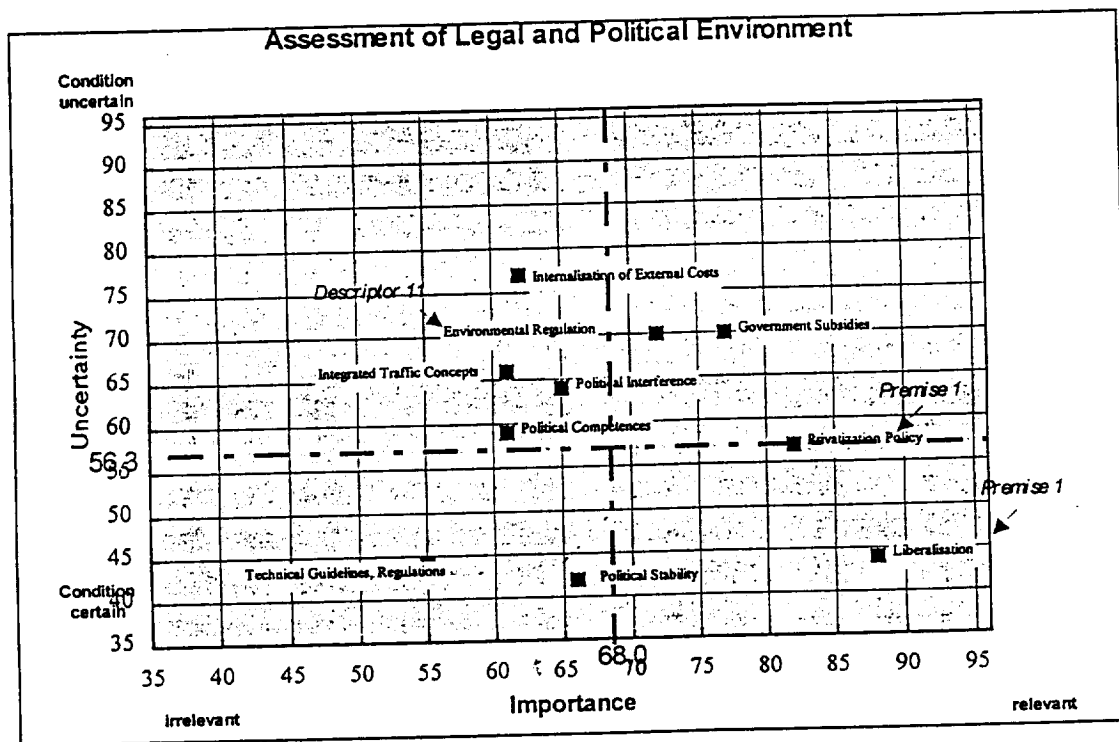
clustered into ten different spheres of influence according to Professor Michael E. Porter's (from Harvard University) industry sector analysis (see table 1), the group of experts were invited to contribute their (qualitative) expertise in order to underpin or dismiss the assumptions put forward by the authors<sup>5</sup>.

Table 1: Spheres of Influence

→ Legal and Political Environment	→ Threat of New Entrants
→ Economic Environment	→ Bargaining Power of Suppliers
→ Socio-Cultural Environment	→ Bargaining Power of Buyers
→ Technological Environment	→ Rivalry Among Existing Firms
→ Ecological Environment	→ Threat of Substitute Products or Services

Source: Dussoye (1997).

Figure 2: Example of a Visualised Result of the U-I-A.



Source: Dussoye (1997).

The number of identified influencing factors at that point was still too large to be processed and to derive conclusions from them within a structured scenario process. For this reason it

pieces by sifting professional journals, books, regulations, standards and recommendations of different organisations (e.g. ICAO, IATA) etc.

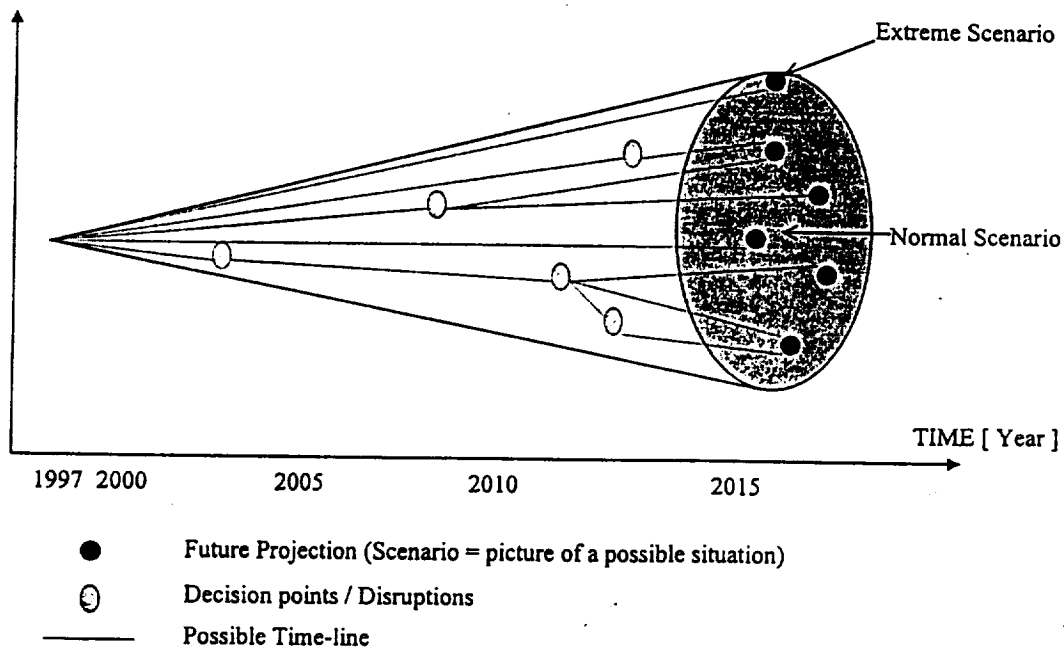
<sup>5</sup> Each expert was asked for his or her comments on recent developments in the European air transport sector and its environment as well as on existing opinions and forecasts of long-term future developments in these fields, see footnote 6.

was necessary to perform a so-called Uncertainty-Impact-Analysis<sup>6</sup> (U-I-A). Outcome was a reduction of the 76 factors to a more operable 18, see figure 2.

#### 2.4 Step 3 - Analysis of Influencing Factors and Their Projection into the Future

Categorise the remaining (18) factors into premises and descriptors, depict their actual state and project trends into the future [e.g. by making use of published forecasts or by conducting primary research (questionnaires, a delphi analysis or by contacting experts)] and write descriptive essays.

Figure 3: Funnel Characterising Future Scenarios



Source: Götze (1993).

A subdivision into six premises and 12 (critical) descriptors<sup>7</sup> was proposed by the authors and distributed to the group of experts along with the feedback from step two for validation purposes and in order to establish a common basis for further discussion, see figure 3 and figure 4.

<sup>6</sup> All the main relevant influencing factors and - if appropriate - additional ones put forward by the respective experts, were statistically analysed, evaluated and finally visualised with regard to two questions:

1. Of what importance or relevance is this influencing factor with regard to the defined problem setting ?
2. How uncertain from today's point-of-view does the state or condition of the respective influencing factor appear to be in the year 2015 ?

<sup>7</sup> Influencing factors with a very likely and unambiguous trend for the given time frame are called premises. Those with multiple possible trends are called descriptors. In either case a plausible explanation regarding their membership of the respective group is necessary, e.g. based on contemporary events or developments.

The alternative assumptions and supplementary information were recorded in so-called 'descriptor essays', see figure 5 and figure 6.

Figure 3: List of Premises

1.	Premise:	Continued liberalisation of the air transport sector and privatisation of related organisations.
2.	Premise:	Expanding international work sharing and ongoing competition between economic areas/ locations.
3.	Premise:	Intensifying application of IT and telecommunication technologies in airline distribution, thus improving the efficiency of the resp. production process.
4.	Premise:	Bottlenecks in infrastructural capacity.
5.	Premise:	Enlarged scale of airlines' product range and product differentiation.
6.	Premise:	Steadily declining average yields (plus its influence on airlines' profitability).

Source: Dussoye (1997).

Figure 4: List of Descriptors

1.	Descriptor:	Economic development within the EU.
2.	Descriptor:	Development of populations' free disposable income.
3.	Descriptor:	Trends in energy prices and availability of energy.
4.	Descriptor:	Fee level charged by relevant providers of air transport infrastructure.
5.	Descriptor:	Air traffic volume and rate of growth of segmented market demand.
6.	Descriptor:	Scale of competition (airline industry in general).
7.	Descriptor:	Importance of customer orientation / customer service(s).
8.	Descriptor:	Loadfactor and utilisation.
9.	Descriptor:	People's attitude to air transport.
10.	Descriptor:	People's time budget, travel behaviour and preferred holiday destinations.
11.	Descriptor:	Regulation of the air transport industry on the basis of its environmental impact.
12.	Descriptor:	Relevance of company branding and image ( with regard to airlines).

Source: Dussoye (1997).

Figure 5: Example of a Descriptor: Scale of Competition (Airline Industry in Gen.):\*

Alternative projections for the future (in per cent):		
Projection A:	Persistent increase in competition.	40
Projection B:	Short- to medium-term increase in competition, but oligopolisation in the long term.	50
Projection C:	Collapse of the currently being forged forms of co-operation and return to a collaboration in the likes of IATA.	10

\*...The percentages reflect the degree of probability of the alternative projections.

**Précis:**

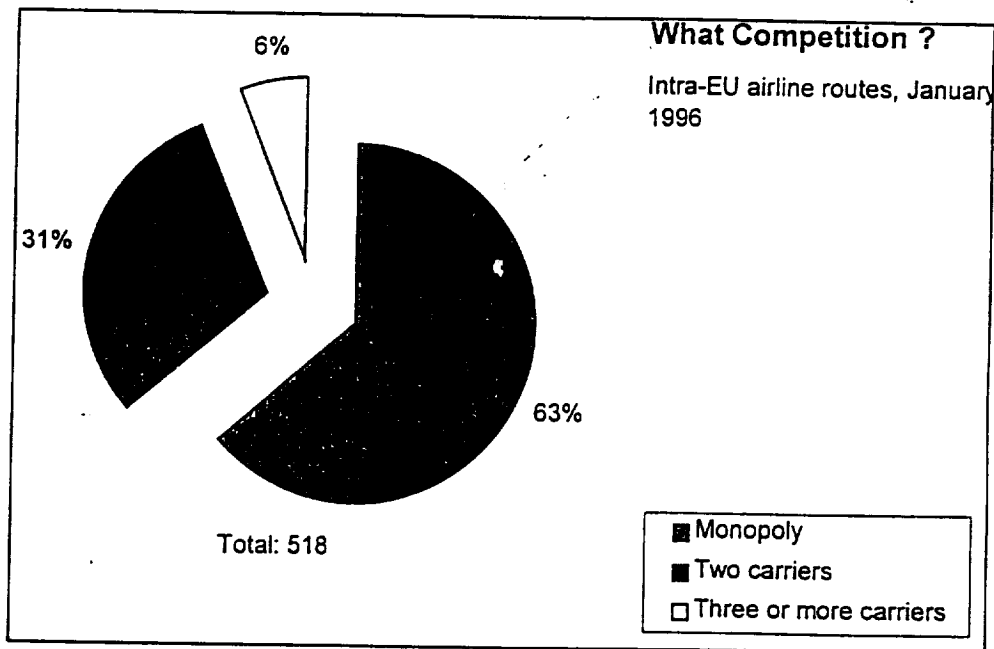
Subject here is the future state of the airline industry sector, particularly regarding the scale of competition between European airlines, i.e. their future co-operations, their size, market share and ownership structure.

**Present Situation:**

Currently, the European airline industry is undergoing a consolidation process. Global route networks, a differentiated product range and seamless travel are being worked out inside new co-operations. Although being important partners, European airlines have to adapt to global trends, e.g. open skies and strategic alliances. Furthermore, the former Eastern European flag carriers (and thus potential future EU-airlines) are being successively privately organised and privatised.

**Notes:**

- Projection A: The increase in competition is due to changing and timely-limited partnerships, thus inducing a fractionalisation of the industry. Incumbent carriers take on the challenge of dynamically growing niche markets by penetrating them, i.e. by offering no-frills point-to-point services themselves, i.e. not leaving them to new entrants.
- Projection B: The initial increase in competition takes place between airline groupings (through M&As and megacarrierisation), but is then reduced when the surviving airline blocs form oligopols after having swallowed or driven their competitors out of (the) market/business.
- Projection C: The envisaged long-term collapse in competition occurs because of classic market failure, thus reviving an IATA-kind of collaboration.



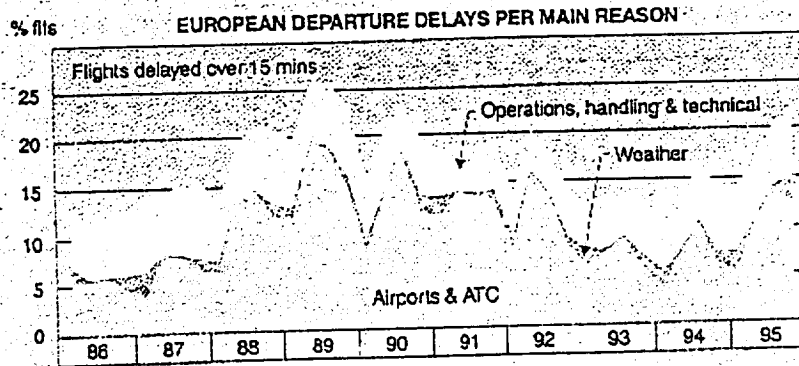
Source: British Midland, in: The Economist, June 14<sup>th</sup>, 1997, p.82

Source: Dussoye (1997).

Figure 6: Example of a Premise: Bottlenecks in Infrastructural Capacity:

**Definition:**

Capacity can be described here as the maximum number of aircraft movements in a typical ATC sector (control capacity) or at an airport (coordination measure) for a given time frame (normally a defined and agreed on peak hour).



Source: Association of European Airlines: AEA Yearbook 1996, p.12

**Past:**

The figure above illustrates the impact of bottlenecks in infrastructural capacity from the mid-1980s until today, which is normally summarised and reduced to the dimension 'flight delay in minutes'.

**Trend:**

It is not only the European category I airports, but also some category II and III airports that already suffer from shortages in infrastructural capacity, especially with regard to slot and gate access. They also lose out when it comes to any sort of expansion. The planned and authorised increase in capacity won't match air traffic growth rates, resulting in a deterioration of the delay situation. A long-term solution is on no blackboard, even though technical and operational means of increasing air traffic capacity are in the pipeline (e.g. harmonisation of ATM systems, transformation of airspace structure). It is the airport capacity limitations that will restrict the potential for future growth.

Source: Dussoye (1997).

## 2.5 Step 4 - Consistency Analysis

**Complete cross-impact matrix (i.e. find out step-by-step whether the simultaneous occurrence of two assumptions is possible or not) and choose and cluster consistent bundles of assumptions.**

The aim here is to correlate the critical descriptors to form consistent and non-contradictory scenarios of the future. For this purpose, each descriptor and its projections are correlated with each other descriptor's projections in a 'cross impact analysis'. The elements of the Cross-Impact Analysis are basically a-priori judgements<sup>8</sup> of meaningful events and a Cross-Impact Matrix which determines how these probabilities are changed if other events occur, thus modifying them to a-posteriori probabilities.

To set up this cross-impact matrix the following question has to be answered: 'If a variant of a descriptor is certain to occur, what will be the impact on all the other descriptors with

<sup>8</sup> A-priori judgements are the best intuitive estimates (given by the experts) for the probable entry of an alternative projection of specific critical influential factors without considering other critical factors.

their variants?<sup>9</sup> This is applied to all critical descriptors and their variants and the result is documented by allowing the allocation of points between 0 and 3, where nil means no impact and three means a strong impact (see figure 7.).

Figure 7: Example Section of a Cross-Impact-Matrix<sup>10</sup>:

	A		B				
	A <sub>1</sub>	A <sub>2</sub>	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>		
						- 3	A <sub>1</sub> lowers the probability of the occurrence of B <sub>1</sub> a lot
						- 2	A <sub>1</sub> moderately lowers the probability...
A	A <sub>1</sub>					- 1	A <sub>1</sub> scarcely lowers the probability ...
	A <sub>2</sub>					0	A <sub>1</sub> has no influence on B <sub>1</sub>
B	B <sub>1</sub>					+ 1	A <sub>1</sub> hardly raises the probability of the occurrence of B <sub>1</sub>
	B <sub>2</sub>					+ 2	A <sub>1</sub> moderately raises the probability ...
	B <sub>3</sub>					+ 3	A <sub>1</sub> raises the probability ... a lot

Source: Dussoye (1997).

With the aid of a core group of experts brought together for 1½ days at TU-B's aeronautical department in mid-December 1997, i.e. making use of group decisions rather than assessing individual questioning results, and by utilising a software tool developed by Daimler Benz' FT4G, exactly 53 scenarios were determined.

From these two scenarios that fulfilled the following criteria were selected for further examination/ study:

1. maximum difference in the forms the scenarios took (see figure ...)
2. greatest possible stability,
3. relevance to (the further research of the underlying PhD thesis).

## 2.6 Step 5 - Creation of Initial or Rough Scenarios

### 2.6.1 General Procedure

#### Select and interpret alternative future scenarios for further study.

The following interpretation of the two favoured air transport scenarios served the purpose of illustrating the interrelationships of the critical descriptors more accurately than by simply listing the obtained forms/ variants of the descriptors. The two scenarios and the information elaborated herein was presented in the form of scenario stories. Extending from the present situation<sup>11</sup> and making use of the preparative alternative projections, these

<sup>9</sup> Or: How would the entry of Projection A<sub>1</sub> (factor of influence A) change the initially assumed probability of Projection B<sub>1</sub> (factor of influence B).

<sup>10</sup> The matrix value records the judgement of how the entry of a "critical influential factor projection" affects all the projections of other critical factors of influence. The other probabilities are corrected upwards or downwards depending on the Cross-Impact-Values.

<sup>11</sup> The projection of the future from the present situation (descriptive vs. normative approach) prevents the creation of purely scientific worlds, raises the plausibility and understanding of the future scenarios and eases the identification of the user/ participant with this procedure.

stories give an interpretation of selected future development paths of the identified influencing factors, i.e. descriptors, see also figure 8.

Figure 8: Comparison of Selected Scenarios

TUB Airline-Scenario		Scenario A <input checked="" type="checkbox"/>	Scenario B <input type="checkbox"/>	in common <input type="checkbox"/>
1	Economic development within the EU	generally moderately increasing	very inhomogeneous growth	stagnating
2	Development of populations' free disposable income	consistent rise	inhomogeneous development (wealthy vs. poor)	generally nominally declining
3	Trends in energy prices and availability of energy	big rise/ occurring problems with availability	medium rise/ no problems with availability	status quo
4	Fee level charged by relevant providers of air transport infrastructure	nominal increase	status quo	nominal decline
5	Air traffic volume and rate of growth of segmented market demand	moderately increasing overall demand	very inhomogeneous growth in demand	decreasing demand
6	Scale of competition (airline industry in general)	increasing competition	competing airline groupings/ oligopolisation	collapse of co-operation forms/ back to IATA
7	Importance of customer orientation/ customer service(s)	higher product differentiation	status quo	declining product differentiation
8	Loadfactor and utilisation	consistently high average LF	seasonally differing LF	LF stabilising on a low average level
9	People's attitude to air transport	increasing acceptance	hardly any changes	declining acceptance
10	People's time budget, travel behaviour and preferred holiday destinations	changing travel behaviour/ more flexible time budgets	"only" slight changes from today	"french" model
11	Regulation of the air transport industry on the basis of its environmental impact	sanctioned through ecological taxes		status quo
12	Relevance of company branding and image (with regard to airlines)	important competition factor		subordinate competition factor

**2.6.2 Brief Description of Scenarios:**

Today's situation: Please take note of section 1.

Alternative projections:

**Scenario 1: 'Back to the Past'**

Crucial Statements:

**Economy:** Despite fierce competition between economic regions an economic downturn becomes visible in the EU. This results in a highly inhomogeneous growth of people's income and a widening of the gap between the rich and the poor. The economic crisis' causes are partly ecological ones, which has led to an increase in ecological taxes.

**Society:** The majority of the European population cannot afford to pay the prices asked for by the airlines in the future. An obvious increase in energy prices being one reason, this results in more people spending their holidays at home. Also from this follows a decreasing acceptance of air transport.

**Air Transport:** Due to the recessive economic situation (downturn) and the drop in the number of tourists a highly inhomogeneous and seasonal growth in the lower single-digit area takes place with regard to air transport. One of the reasons for this is that only the better-off are able to spend their holidays abroad and this only at certain times. The main drive comes from business travel.

**Competition:** The remaining air travelers are being aggressively courted by the remaining airlines which have re-invented and work together (with regard to service standards and competition issues) in an IATA-like



body. The customer benefits from an improved product differentiation and attaches great importance to brands and image, thus transforming these facets to comp. Advantages (e.g. over non-IATA carriers).

**Scenario 2: 'Growth Fraught with Mishaps'**

**Crucial Statements:**

- Economy:** An increasing competition between (European) regions leads to winning and losing parties, thus increasing regional and socio-demographic disparities, e.g. in regional free disposable income.
- Ecology:** No problems are foreseen regarding the supply with energy. Even though no direct link could be established between air transport and the changing climate, there still exists an ambivalent societal behaviour towards this mode of transport. One result of this is the introduction of moderate ecological taxes (this being the first step in the process of internalising external costs).
- Infrastructure:** Infrastructural shortcomings (also with regard to the so-called environmental capacity) become visible more and more, thus rendering infrastructural capacity (especially airport access) a scarce commodity, thus affecting the price for their usage.
- Demand:** Growth in demand being moderate and steady has its main causes in changing travel behaviour and a more flexible time budget (demand side) as well as a better utilisation and higher load factor (supply side).
- Competition:** The remaining air travelers are being aggressively being courted by the few remaining mega-airline groupings. The customer benefits from an improved product differentiation but does not attach great importance to branding or image.

## 2.7 Step 6 - Sensitivity Analysis

**Introduce uncertain and/ or disruptive events, perform sensitivity analysis.**

Trends and events which from today's point-of-view are not considered being very likely were not taken into consideration when building the rough scenarios. In order to supplement the potentially possible development depicted in the scenario process so far, conceivable but unlikely internal or external events occurring abruptly and affecting the problem area in a positive or negative way may be and actually were integrated. The significance of these events can be shown when one compares the rough scenarios generated so far with the newly possible ones, as the scenario funnel is enlarged asymmetrically. As a sensitivity check this integration of possible, but unlikely events may help cement the stability of the derived solution as well as the certainty of the derived business recommendations since the anticipation of unexpected development makes it possible to plan preventive measures or totally new strategies. Three incidents were considered and studied which, however, did not change the essential statements of the two selected scenarios.

1. Dramatic increase in energy prices.
2. Dramatic deterioration regarding infrastructural capacity.
3. Dramatic increase in air traffic volume.

## 2.8 Step 7 - Detailed Scenarios and their Implications

**Prepare forecasts (i.e. 'construct' highly detailed scenarios) and analyse and study the implications for key decision scenarios.**

This last step did not and could not form part of the scenario process – since also direct competitors contributed in the first phases and/ or took part in the workshop- conducted here, since it has to be left to each of the participants to create their detailed scenarios based on the outcome of the documented process or otherwise, i.e. after identifying what are the main relevant pressures or influencing factors for analysing the future framework of the European airline industry.

## 3 Where to go from here ?

The evaluation of the scenarios in parallel with an analysis of the surrounding environment is another important point-of-departure when looking at the scenario building process and its framing activities. As the construction of scenarios is not an end in itself, the success of this process is based on the exploitation of its results in the ensuing planning phases. An important function of scenarios concerns the early recognition of emerging future trends and changes of our assumed picture of the world so as to adjust our unfolding strategies.

What can be learnt from the outcome of this scenario process is that future research in air transport has to have its focus on 'Rivalry among Existing Firms' and the 'Threat of New Entrants' (in the terms of Michael E. Porter). This is due to the fact that the overwhelming majority of very important and very uncertain influences were identified and attributed to these spheres of influence<sup>12</sup>. Even though some work has been undertaken in the past – especially with focus on airline-related barriers to market entry - further research is pivotal to stay abreast with these changing and very dynamic parts of the analysed industry sector.

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<sup>12</sup> Based on this scientific discovery Mr Dussoye is currently working out a competitor analysis in order to identify and cluster competition patterns emerging from within the European airline industry..

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8<sup>th</sup> WORLD CONFERENCE ON TRANSPORT RESEARCH

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**CITY AIRPORTS AND SUSTAINABLE URBAN  
DEVELOPMENT: THE CASE STUDY OF FLORENCE**

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## PREFACE

The role of infrastructure in the regional development process has been studied for a long time without specifying the direction of the causal relationship. This seems to be particularly true as far as the airports are concerned, which are often considered as strategical determinants of regional growth but also as a factor induced -in other contexts- by the development process itself.

In the first stages of development, it can be supposed a weak demand as far as air transport is concerned; in this scenario the decision of building a new airport -for instance in the capital city of a country- might be considered as a supply-induced policy measure.

In the following phases of growth, the demand for an adequate endowment of transport infrastructures becomes the prevailing factor in the decisions of carrying out investments in this field.

In this framework, city-airports may be seen as "second generation" products if compared with the traditional airports; they meet, in fact, a more restricted and qualified part of mobility demand and are components of a more general "city marketing policy" induced by the need of the cities to be active in urban competition.

The city airport of Florence -which showed in few years an important growth of traffic- constitutes the field of empirical analysis of the paper.

After a short presentation of the present phase of Florence area development, as well as of the city-airports' case, the present and the future of Florence airport is described; in this part specific emphasis has been devoted to the 2010 demand's forecast by means of a gravity modal-split and econometric model. The second part of the paper analyses the effects of air traffic from the point of view of their typological nature (temporary, permanent, short and long term) taking into account, with a theoretical approach, the unavoidable trade-off between economic benefits and environmental effects.

## 1. THE PRESENT PHASE OF FLORENCE AREA DEVELOPMENT

### 1.1. General characteristics of the economic-social structure

The Florentine area comprises 10 municipalities in a densely urbanized area covering 552 sq. km with over 600,000 inhabitants.

The level of income as well as the well-being is the highest in the region and one of the highest in Italy, with a correspondingly lower level of unemployment.

The general characteristics of the social structure are typical of a metropolitan area which has developed with strong tertiary characteristics: a marked presence of the upper class, a substantial number of professionals and executives; a high activity rate of women, a percentage of university graduates 70% above the regional average.

The area has the greatest concentration of the region's productive activities (over 12,000 firms with almost 90,000 employees), mainly concentrated in the public and private tertiary sectors (finance, tourism, distribution, in addition to public management services), although in the western part of the area there are several important engineering, electronics and chemical, not to mention fashion, industries; the agricultural sector is practically non-existent.

The city is very open-minded in its relations with other countries and represents the "gateway" to Tuscany for the rest of the world. Florence boasts a centuries-old specialization in trading activities and has a sound tradition as far as tourism is concerned, as well as a long-standing relationship with the Anglo-Saxon world, consolidated by the presence of many international cultural institutions. This is confirmed by the fact that every year over three millions of foreign visitors spend at least one day in Florence and foreign trade activities amount annually to over 10 billions of dollars.

Historically, the Florentine area is the region's cultural and political centre and in this sense exerts a preponderant influence over other parts of the region: from an economic point of view, however, it is not adequately connected with the industrial districts (made up mainly of small and medium producers of consumer goods, most of them exported) in the rest of the region, which promoted the "take-off" of the Tuscany economy in the 'fifties and 'sixties. The tertiary sector, which has always existed in the city, is in fact more public than private, employs more office workers than managers, is more closely linked to training than to advanced research

and numbers more tourist than financial activities. The typical functions of European metropolitan areas, in fact, even if are present in the Florentine area, have not been developed to the extent necessary to establish a point of reference for the region's industrial districts. As a consequence, they often risk being left out of the competition with other European areas or are obliged to resort to other cities in central/northern Italy (as for example Milan or Bologna) to satisfy their requirements.

Florence has recently been endeavouring to better integrate its development with the rest of the region, by guaranteeing a series of activities and services for exhibition structures, cultural initiatives, research centres as well as transport infrastructures, in order to improve accessibility to and from the area.

This process is however still underway, hindered on the one side by a widespread tendency to "keep things local", leading to a proliferation of similar initiatives rather than to specialization and concentration, and, on the other, by the slowness in decision-making, particularly in carrying out major public works.

## **1.2. The relationship between the inner city and its hinterland**

The conflictive relationship between the Florentine area and other areas of Tuscany is reproduced, *mutatis mutandis*, within the area itself, i.e. in the relationship between the inner municipality and the surrounding ones: over the last twenty years the latter have grown up following decentralization of the population and production activities from the city of Florence, and this had led to intense functional relations (home-work exchanges). There is however a marked autonomy (and diffidence) on the part of individual municipalities where the central municipality is concerned, due, among other things, to the lack of a metropolitan authority to co-ordinate services over a widespread area.

Wide scale organization of services is therefore only sporadic and often regards only small municipalities which join together to gain economies of scale. Most of the services affecting the territory (waste disposal, depuration plants, road systems, airport) provide frequent cause for dispute between the hinterland and the central municipality, which is often accused of trying to transfer its environmental diseconomies to the surrounding municipalities, while a similar accusation in the reverse is made (with relative repercussions of fiscal spillover) with regard to the institutions of regional scale (hospitals, universities, judiciary offices...) which contribute in a relevant way to the congestion of the centre of Florence.

It is obvious, therefore, that there is a marked asymmetry in the perception of problems concerning "good neighbourly relations" between Florence and the surrounding municipalities; in particular, perception and protest are often grossly out of proportion to the importance of the problems. To cite two examples: for many years the lower course of the river Arno has suffered from the lack of a water depurator, due to Florence municipality's slowness in building the plant, with consequent poor quality water in the river downstream of the city; this has not however given rise to any serious protests. Conversely, the exportation of environmental effects which are of significantly less importance, as for example those produced by the airport (which is obviously used by a far greater number of people than the inhabitants of Florence municipality) gives rise to well-organized protests and lobbies demanding closure or, at least, a severe reduction of the airport activity.

## **1.3. Quality of the environment and urban development**

As will be seen more clearly below, the particular attraction of Florence, not only as a sightseeing spot for tourists, but also as a permanent location for companies or as the seat of international institutions, depends not only on the wealth of its cultural heritage or the traditional vivacity of its international relations, but also on the pleasant natural environment of the city and surrounding area.

The Florentine area's particular morphology, an alluvial plain through which the river Arno flows, surrounded by hills on three sides, intensely urbanized (see figure 1), and with heavy traffic, makes for particularly difficult environmental conditions; the environmental load is in fact well above average for the region (over 6 times) with almost 3 thousand inhabitants per sq. km. The air pollution it is particularly severe and road traffic plays in this field a great role, causing sometimes limits to private cars when pollution exceeds certain limits. As far the noise pollution is concerned, it is estimated that most dwellings are subject to a noise level exceeding 65 dB during the day and 55 dB at night.

As result, while, on the one hand, careful town planning has protected the landscape,

especially in the highly prized hilly areas. On the other, there has been a worrying increase in air and noise pollution. Air pollution has been given greater publicity due to repeated decisions, referred to above, to temporarily restrict the circulation of private cars in the event of some pollutants exceeding certain levels. Italian law pays less attention to noise pollution, although (due to the city's very narrow streets and heavy traffic) it certainly does not escape the notice of citizens and visitors to the city, who comment on this negative aspect in opinion polls and in statistical evaluations on their judgement of the city.

Florence's administrators are well aware of the necessity to avoid compromising one of the fundamental elements of Florence's national and international image, but the policies implemented to date appear to be aimed principally at limiting damage and intervening in those areas of the city which are visited by the greatest number of tourists (the monumental historical centre).

More radical intervention is however necessary, calling for short as well as medium-long term operations with heavy investments (a modern tramway network, for example) involving the whole territory (requalifying, for example, the new suburban areas) if quality of the environment is to become a positive element in the urban marketing policy referred to in the following paragraph.

## 2. CITY AIRPORTS AND URBAN DEVELOPMENT

### 2.1. Airports and city marketing

The recent diffusion of city airports in Europe and North-America appears to come into the wider-range phenomenon of the competitive challenge between urban areas on European and world scale - a challenge which is more evident than the traditional challenge between national systems. The competition is based on the acquisition of high quality functions in the institutional and business services contexts and has become keener following reorientation of economic core towards great urban areas. City marketing is the basic instrument of this competition and includes a series of interventions to improve and promote urban services. This has been implemented by the major cities of industrialized countries for the purpose of guaranteeing to the urban system both certain competitive advantages in terms of market outlets for its firms and the location in the area of high value added activities.

Competition is concentrated in the services sector - whose aim is to increase the efficiency of the productive system (exhibitions services, transport infrastructures, financial services) and to improve the urban environment (town planning, public green areas and cultural activities).

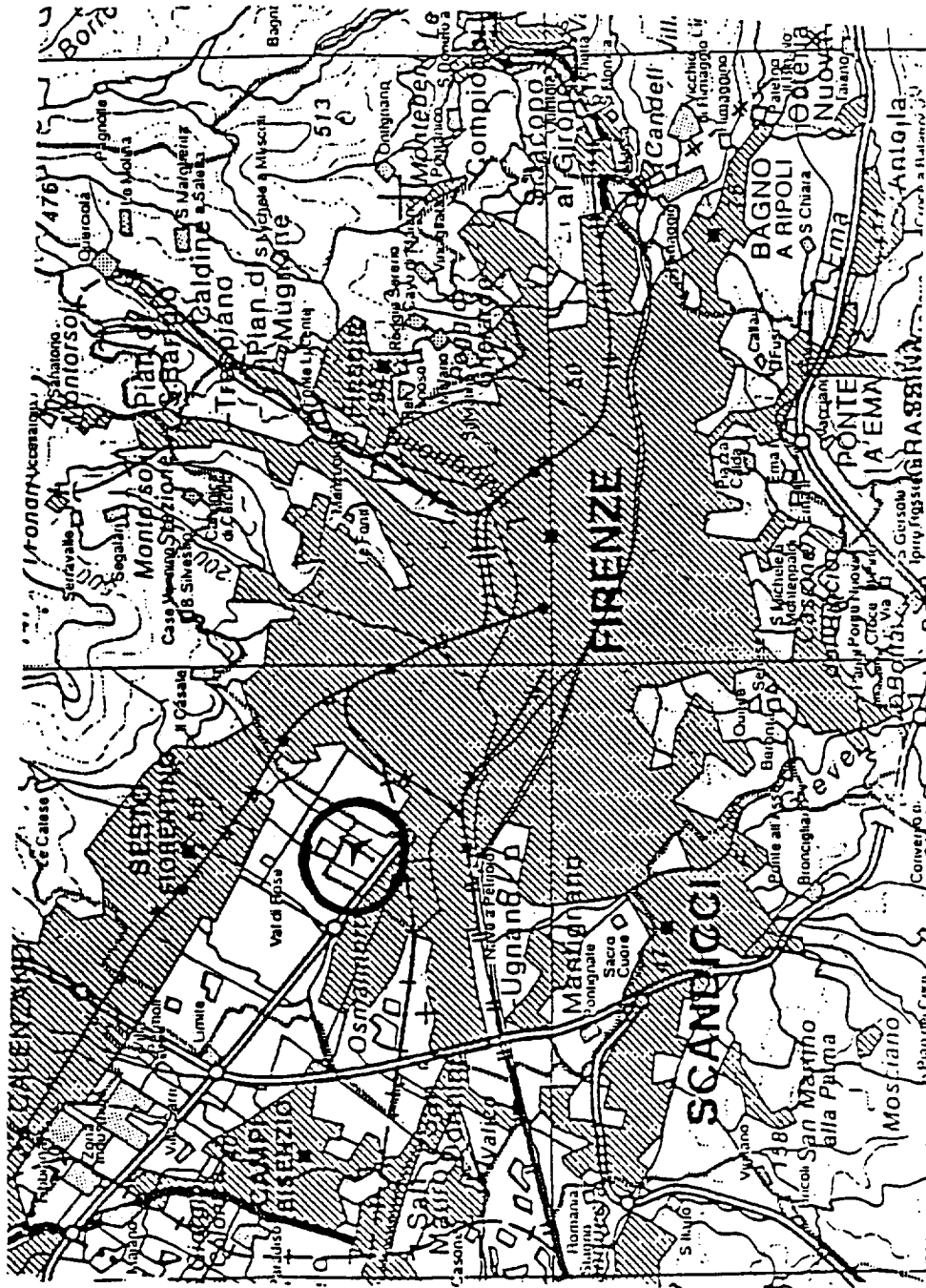
In this context, air transport services are a decisive element, considering that "The regional airport is part of the infrastructure of urban regions. The development of the regional airport should therefore be an integrate element of total policy in the cities concerned" (Van den Berg 1991). And recent studies on the relative competitiveness or the degree of internationality of European cities have pointed precisely in this direction. Probably the most well-known is "Le villes européennes" (DATAR-RECLUS 1989), which for this purpose has used a series of indicators among which the presence of air transport infrastructures plays a significant role.

But this element is not univocally correlated in a positive sense to urban development: as the above writer points out, "an airport is acceptable if the positive effects on the region's accessibility overcompensate any negative environmental effects weighted with the prevailing social preferences (Van den Berg, op. cit). There are, in fact, potential contradictions in the elements of city marketing: accessibility to the air is essential to urban development but its impact should not be such as to induce a greater number of negative elements.

### 2.2. Development of the city airports

Up until now city airports have been subject to a logic of "bound growth", split between environmental problems and development objectives. As far as the environmental problems are concerned, the advent of city airports has been made possible by the technological evolution that has taken place in the aircraft industry. Major aircraft industries have, in fact, developed a series of smaller aircraft, which have a lower impact on the environment, but give a greater guarantee of safety and travel comfort comparable to that of larger aircraft. In this way a new generation of turboprop aircraft, seating from 30 to 70 passengers, and an increasingly numerous group of

Figure 1 THE METROPOLITAN AREA OF FLORENCE





"regional jets" which carry up to 100 passengers, have been introduced and are competitive with larger jets in terms of running costs. Besides requiring less space for take-off and landing than other aeroplanes, these aircraft have benefited from the technical progress made in the field of noise reduction, which has involved the whole aviation industry. All models operating at city airports come under "chapter 3", a group which, in accordance with international air transport organization regulations, unites aircraft having a lower noise impact. On the other hand, city airports had helped the economic growth of many urban areas providing the offer's response to the evolution in demand: against a demand for air transport which was increasing quantitatively at rates which far exceeded income, major intercontinental airports were offering increasingly less satisfactory services to the more qualified and wealthy demand segment, in other words, to business travellers who place a higher value on their time than other passengers. Lengthy access times (major airports are on average 20/40 kms. away from the town centre), extended baggage pick-up times, an ever-increasing number of delayed flights due to traffic congestion are, by now, frequent at big airports. The most recent figures for four American metropolises (Los Angeles, Houston, Dallas and Chicago) show that 25/30% of flights at their international airports are delayed, against 15% for corresponding city airports. These latter structures are able to offer frequent connections by using smaller aircraft and faster-moving ground services and are, in addition, more easily accessible, since they are located within the urban area. In most cases they are first generation airports which have been progressively abandoned for passenger traffic due to their closeness to the city's built-up area, then assigned to general aviation and later rediscovered and revaluated to respond to this new and more exacting demand segment.

The sole exception to this rule is London City Airport (9 km. from the centre), built in 1987 in the Dockland area, which developed amid a series of complex vicissitudes, mainly after 1992. The runway was extended to the present 1200 metres and the airport was later connected by rail to make it more easily accessible from the centre of London. Traffic has grown rapidly from 150 thousand to the present 800 thousand, with a network of flight connections which includes the main western European countries.

Again in the United Kingdom, Belfast city airport (2 km. from the centre) is noted for having recently exceeded one million passengers after just a few years of rapid growth. This case is particularly interesting due to the presence, next to the airport, of a natural park for the conservation and protection of the fauna.

Of a more traditional nature, when compared with the historical origin of the city airports referred to above, is the case of Stockholm-Bromma (8 km. from the centre). Until 35 years ago it was Stockholm airport, after which it fell into decline due to environmental problems up until recently (1992) when a regional jet service was introduced rapidly leading to the transport of half a million passengers.

Berlin Tempelhof (6 km. from the centre) has followed a very similar course; built in the twenties', it grew until the seventies' when, because of the amount of traffic and type of aircraft that operated there, congestion became untenable; it was rediscovered in the 'nineties and presently serves one million passengers.

Lastly, another interesting case is Toronto city airport (situated on an island opposite the city to which it is linked by ferry) which has encountered numerous obstacles owing to continual conflict in public opinion over the desirability of conserving the airport. The ban on the use of regional jets at this airport is seriously jeopardizing its possibility of survival; traffic has in fact dropped from 450 thousand in 1987 to less than 200 thousand in 1994.

### **3. THE GROWTH AND THE FUTURE OF FLORENCE AIRPORT**

#### **3.1. The regional airport system**

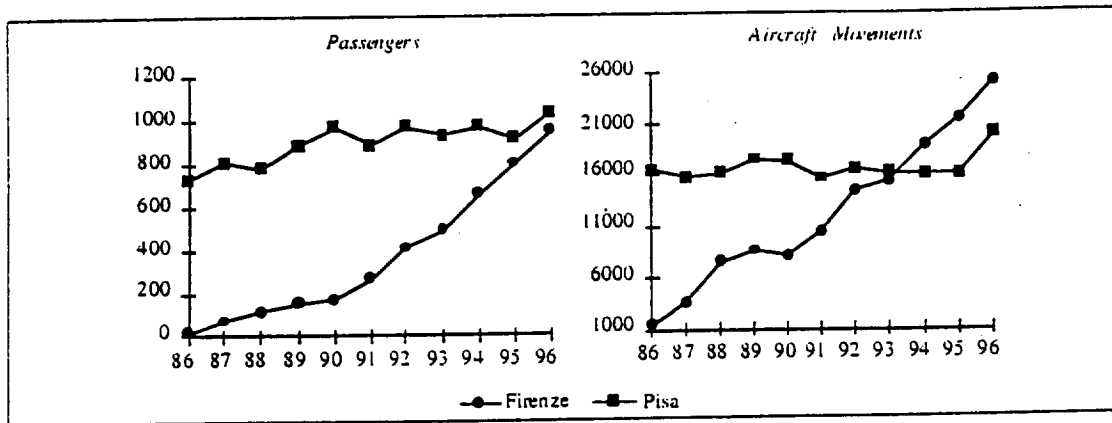
The region of Tuscany, of which Florence is the chief city, is particularly lacking in air infrastructures; in 1985 only 700 thousand passengers used regional airports, just 2% of the national total. Ten years later this figure increased to 3% (for a total of 1.6 million passengers) which is exceedingly low considering the region's economic and demographic relevance when compared with the whole of Italy (6-7%). Considering the Tuscans' marked inclination towards mobility (10% higher than the national average) and the region's strong tourist attraction, it would appear that a significant share of traffic, estimated at around one and a half million passengers yearly, is discouraged and diverted due to the lack of air infrastructures.

The main reason for this situation is the regional government's long-standing decision to

maintain Pisa airport as the region's sole airport - 80 km. from Florence - one hour's travel by road or rail. During the long period (in the seventies' and eighties') when it was the region's only airport, Pisa airport maintained a modest growth pattern and never exceeded 1 million passengers.

The pressure of demand, which has grown and remained unsatisfied due to Pisa's poor accessibility (the region's demographic, economic and political centre is concentrated around Florence) has prompted the regeneration of Florence airport, which was for a long time used for general aviation purposes but is now surrounded by production plants and residential areas. Only the advent of the new "chapter 3" turboprop aircraft has made it possible to relaunch this airport with a one-way runway which until 1996 was 1400 metres long. This limitation, however, has not prevented a very rapid growth in traffic so that over the last ten years Florence airport has exceeded that of Pisa in terms of air traffic and has equalled it in number of passengers (see figure 2).

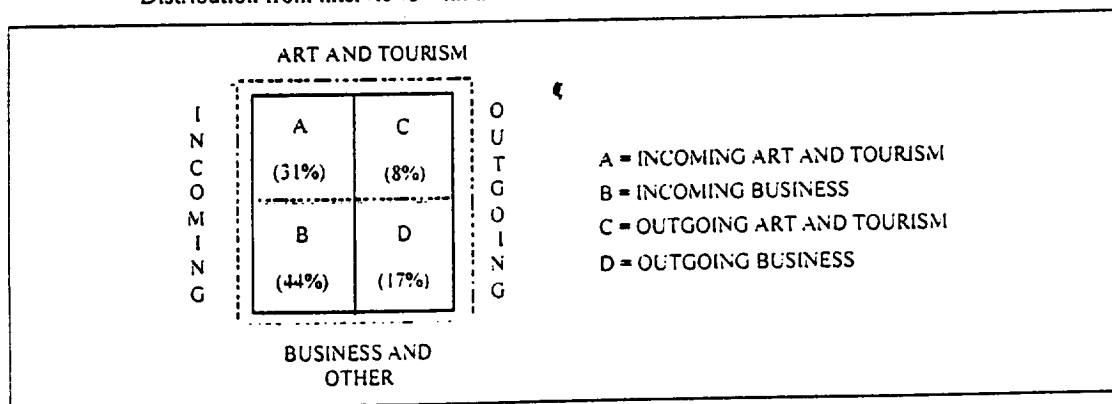
Figure 2 PASSENGERS AND AIRCRAFTS MOVEMENTS OF AIRPORTS OF FLORENCE AND PISA  
Passengers in thousand of units



### 3.2. The characteristics of demand and supply

The reasons for traffic growth at Florence airport become clear upon analysing the typology of passengers: i.e. travellers who use international rather than national flights, usually business men (60%) (see figure 3) and travellers who often make the outward and inward flight on the same day, as emerged from interviews with a sample set of Florence airport users.

Figure 3 THE USERS OF FLORENTINE AIRPORT  
Distribution from interviews with travellers



This latter factor is of particular importance because the supply of flights has grown mainly due to an increase in the frequency of daily flights to the main destinations - Paris, London, Munich, Rome and Brussels - rather than to an increase in the number of linked cities. In short, the airport's key to success appears to be time-saving in reaching the principal European cities, and is aimed at business traffic (or better-class tourism) with high value of time and, consequently, high willingness to pay (the average amount spent daily on the ground by an

"incoming" traveller is approximately 420 thousand lire).

Further confirmation of these characteristics can be seen in the heavy concentration of flights in the early morning and evening (almost half the movements take place before 10 a.m. and after 6 p.m.) and almost total lack of seasonal traffic (maximum average annual variances do not exceed 30%).

This type of traveller requires a series of various ground services that are generally more qualified than those offered by airports dealing mainly in tourist traffic; this was borne out during direct interviews made at Florence airport; the very rapid quantitative growth has caused problems in the quality of reception (as for example, queues at check-in desks) of which those interviewed complained bitterly.

### 3.3. The forecast evolution in 2010

A detailed evaluation of the forecast demand in the medium term at Florence airport (IRPET, 1997) has revealed significant growth margins. The estimate has been based upon a model that proceeds by successive logical stages which compare the generalized transport costs (assessed in comparative terms) of an aircraft with other competitive means. On the basis of this model it has been possible to measure localized demand, in other words, the demand determined merely by the economic convenience (taking into account the time and cost of transfer) of using various airports.

More precisely, the whole model is made up by three different submodels: the first one aiming at evaluating the total flows among  $n$  origins and  $n$  destinations; the second one evaluates how many of these flows have an economic convenience to use aircraft in some part of the entire trip; the third one analyses how other circumstances influence the above economic convenience to determine the actual demand.

The first submodel is a traditional gravity model applied to two different kinds of trip: tourism and business. Therefore two different  $n \times n$  origin-destination (O/D) matrices are obtained, where  $n$  is the number of origins and destinations. In our case  $n=132$  and is composed by 95 Italian provinces and 37 foreign regions.

In the second submodel these flows are splitted into two different transport modes (aircraft mode and other modes) according to times and costs of transport. More precisely, if  $GC$  is the generalized transport cost obtained summing up the transport costs  $C$  and the value  $w$  that each subject ascribes to the time  $T$  spent in the trip ( $GC = C + wT$ ) and if there are two different transport modes, mode 1 (aircraft mode) is preferred to mode 2 (other modes) if the value that the passenger ascribes to time savings by using the mode 1 is greater than the major cost payed:

$$w > (C_1 - C_2) / (T_2 - T_1)$$

The value that each passenger ascribes to his time depends upon his income and the kind of trip (business or tourism). Assuming that:

a) the value of times in business trips depends on the value added of the worker;

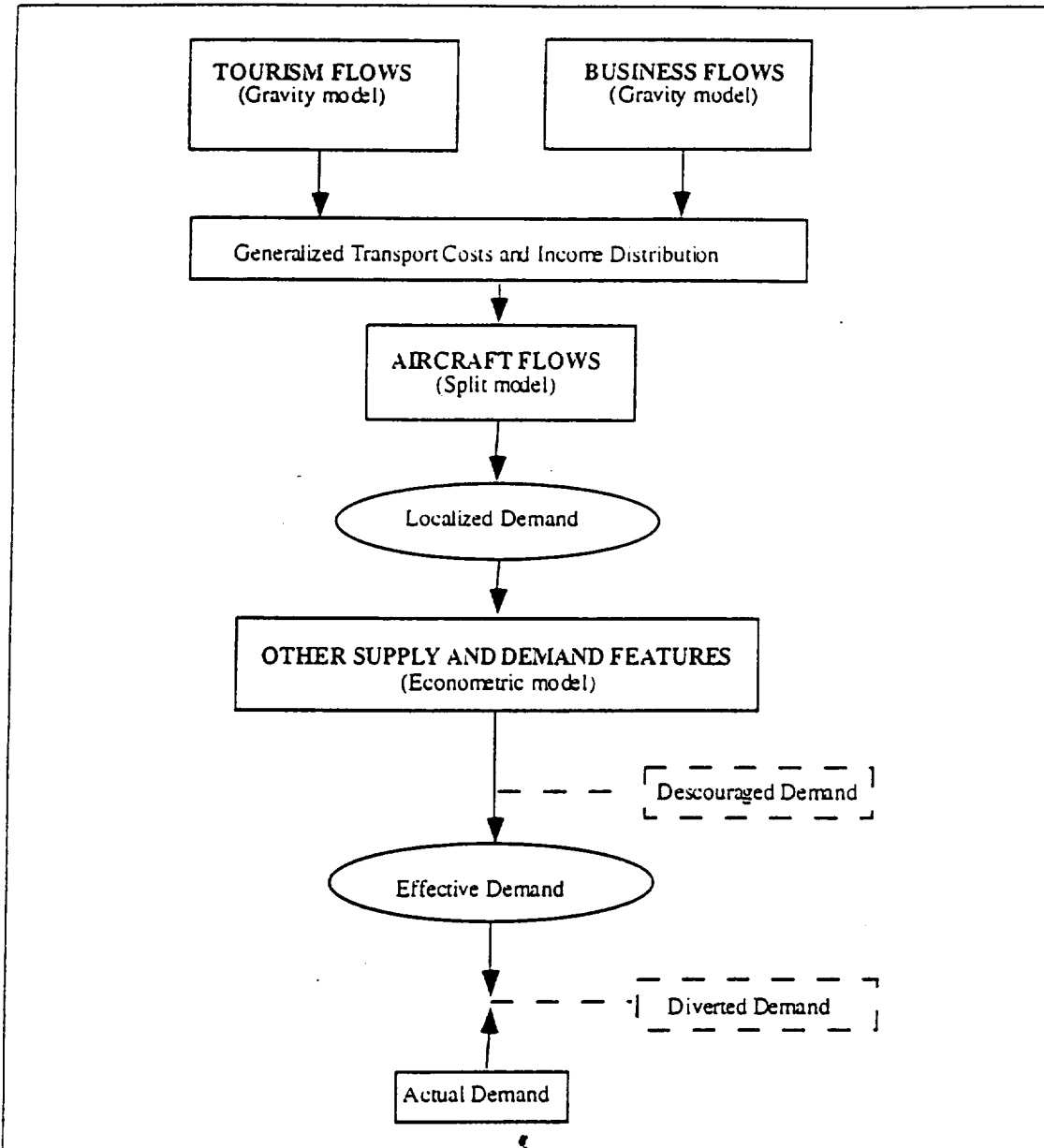
b) the value of times in tourism trips depends on the family disposal income;

and, in accordance with these two income distributions, it is possible to split the two above O/D  $n \times n$  matrices in  $m \times m$  O/D matrices of aircraft flows (in our case  $m=50$ )

This result defines a generic economic convenience to use each airport in consideration of costs and times of transport and passenger's income; i.e., it determines a kind of «localized» demand mainly based on the supply and the demand location.

The third submodel is an econometric one establishing how this «localized» demand becomes «effective», by means of the introduction of other variables defining more exactly the demand and the supply characteristics.

Figure 4 THE FORECAST MODEL



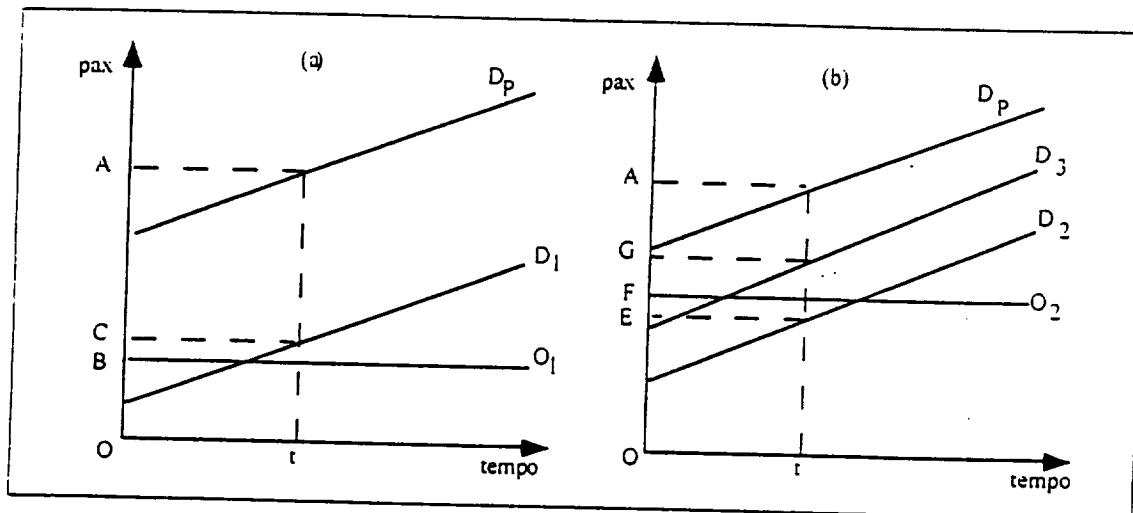
The difference between «localized» and «effective» demand is a kind of «discouraged» demand (if the first is greater than the second one), whereas the difference between «effective» estimated and «actual» observed demand is an indicator of the «diverted» demand (if the first is greater than the second one).

From a comparison between the localized demand and the actual traffic (i.e. satisfied demand) it emerges that, out of all Italian airports, Florence has the highest level of disequilibrium; in short, localized demand is almost three times that presently satisfied.

In reality, not all localized demand is in effect revealed, since it is influenced by a subjective perception of the value of one's time and individual preferences for a certain type of transport. It is also necessary to consider other elements related to the supply (frequency, flight times, the possibility of reaching intermediate destinations on long-distance journeys and so on) which end up by making some potential travellers divert to other airports. Bearing in mind that the supply characteristics influence the demand, it is possible to make a consideration that can be referred more generally to all cases in which the interaction between demand and supply takes place in transport infrastructures with a rationed offer (in our case, small airports in high mobility areas). In fact, from a simple evaluation in static terms it could be assumed that an

adequate increase in the supply of air transport would lead to localized demand being fully satisfied, to the point of eliminating the diversion phenomenon. In reality, in dynamic terms, this does not happen because an increase in the supply immediately gives rise to an increase in the demand, with the result that on the one hand it leads to an increase in the number of users (and of satisfied demand), while on the other to a variation of uncertain entity in the diverted demand. The situation can be seen more clearly in figures 5a and 5b.

Figure 5a and 5b SUPPLY AND DEMAND IN A STATIC AND DYNAMIC SCENARIO



To a supply of  $O_1$  corresponds a «localized» demand ( $D_p$ ), and an «effective» demand ( $D_1$ ): at a time  $t$  the persons interested in using the stages included in supply  $O_1$  are equal to segment  $OA$ . The other characteristics of the supply are such as to discourage users  $AC$ , so that the demand that actually turns to the airport is  $OC$ ; the  $BC$  part of the demand is therefore obliged to turn elsewhere. If the supply increases ( $O_2$ ) (in the frequency of flights rather than in the number of flight destinations) this immediately affects the «effective» demand which shifts upwards, while «localized» demand remains unvaried. Two different situations may arise, with the new demand respectively at levels  $D_2$  or  $D_3$ . In the first case, the increase in demand, prompted by a variation in the supply, would not be such as to maintain a share of the «diverted» demand; in the second case, however, elasticity is such that the segment  $GF$  would remain unsatisfied despite the new supply.

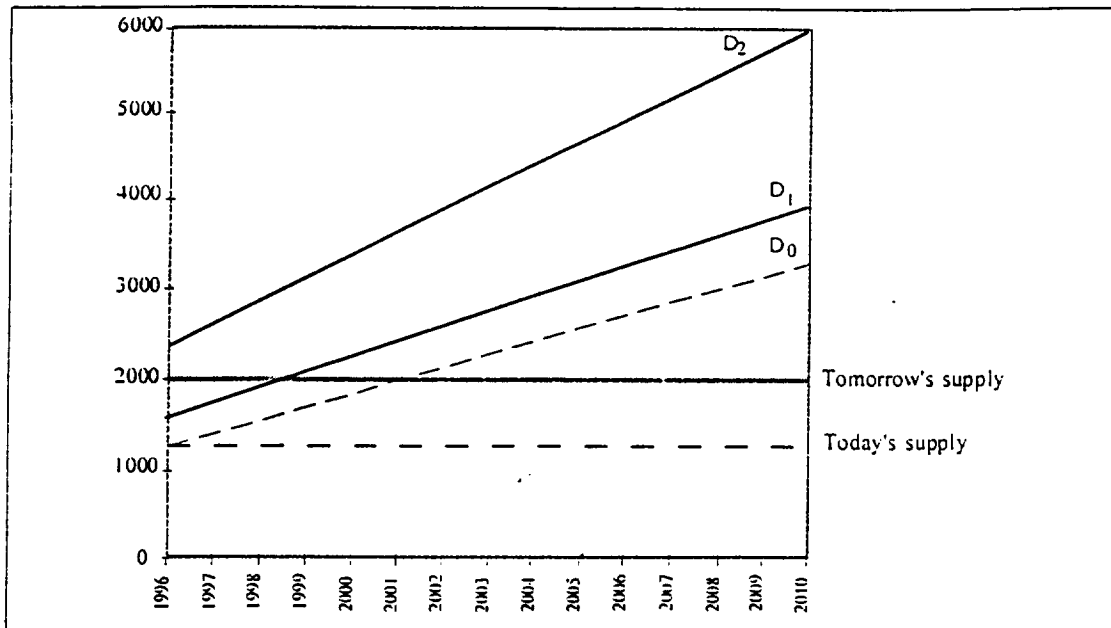
Broadly speaking, the latter represents the situation of airports like Florence, with a high potential demand, as can be seen when the above assessment model is applied to the 2010 scenario. In this perspective, to verify the variability of demand, we have considered the following influencing factors:

- the growth in general mobility, on the basis of fairly low income growth forecasts;
- the increase in high speed railway lines currently being carried on in Italy which will greatly reduce travelling times on main routes;
- the variations in air and railway fares, in the context of airline deregulation in Europe and of the consequent increase in competition;
- a realistic increase in the offer of flights from Florence airport (up to approx. 2 millions seats).

In this context two alternative hypotheses of demand growth have been considered for Florence airport, the first of which ( $D_1$ ) would bring the demand for seats up to almost 4 millions, the second ( $D_2$ ) to almost 6 millions (see figure 6).

Figure 6 DEMAND AND SUPPLY IN THE AIRPORT OF FLORENCE: FORECAST EVOLUTION IN 2010

Thousand of passengers yearly



In the first case we have assumed a particularly aggressive policy on the part of the two airports near Florence (Pisa and Bologna) which would to some extent be in competition; in the second, we have assumed a substantially unvaried situation compared with the present one. In both situations, however, already from next year, the demand would grow above the new supply. At the end of the period of time considered, the diverted demand would therefore be 2 million passengers in the less dynamic scenario, and almost double in the scenario represented by curve D2.

#### 4. THE EFFECTS OF AIRPORT OPERATIONS

##### 4.1. Present and forecast effects of air traffic

To evaluate the sustainable development of airport activity we have endeavoured to assess the economic and environmental effects of traffic expansion, having as a reference the estimated effects on present traffic (1995 figures, 800 thousand passengers and 21 thousand air traffic movements annually).

The effects of airport operation can be summarized as in the following table.

Table 1 THE EFFECTS OF AIRPORT OPERATIONS

SUBJECTS EFFECTS	COMMUNITY	USERS
<b>Social-territorial</b>		
- short term	Impact on environment	Utilization of free time
- long term	International relations Urban organization	Effects on relations Cultural effects
<b>Economic</b>		
- short term	Impact of "on and off" airport activities (employment, tourism...)	Reduction in generalized transport cost
- long term	Location of new companies Attraction of exhibition and cultural activities	Competitiveness increase Market area widening Operational innovations

Some effects have been listed merely as a promemoria and can only be assessed through multicriteria qualitative analysis models. By this we refer to the improvement in relations with the rest of the world from which the entire community would benefit, and to the direct effect on relations and cultural effects for users.

Insofar as the economic effects are concerned, we have given only a broad estimate of the effects of airport operation, bearing in mind that for some (long term in particular) only general indications can be given.

#### 4.2. The short-term effects in Tuscany

As regards the short-term impact (in other words, the effects seen immediately after airport operations have begun), this consists of the multiplicative effects of economic activities connected with the airport and the ensuing reduction of generalized cost of transport.

Regarding the first point, an estimate has been carried out of *the economic impact of the «airport company»*, in other words, of the various economic activities (public and private transport firms and related services) linked directly to airport activity and which operate both within its boundaries and in other parts of the city (the former are known as "on airport", the latter "off airport" activities).

The following estimates are the result of applying the IRPET bi-regional input/output model to 1995 turnover and employment data (see table 2).

Table 2 OVERALL ACTIVATION OF THE AIRPORT IN TUSCANY - 1995  
Values in millions of dollars

	Employees	Value Added	Turnover
«On airport» activities	652	..	90.0
Indirect effects	566	31.9	
Induced effects	190	10.3	
TOTAL EFFECTS	756	42.2	
«Off airport» activities	3.359	...	257.5
Indirect effects	3.752	164.5	
Induced effects	1.024	56.9	
TOTAL EFFECTS	4.776	221.4	
TOTAL ACTIVATION (Indirect+induced effects)	5.532	263.6	
TOTAL TURNOVER			347.5

It is estimated that approximately 650 people were employed in "on airport" activities during 1995 with a gross turnover of 90 millions of dollars, while 3 thousand people were employed in "off airport" activities for a total turnover of almost 260 millions of dollars; the induced effects are calculated under the hypothesis of endogenous consumption. To these effects must be added those produced throughout the rest of Italy, which are approximately a quarter of those produced within the region. Lastly, it should be noted that while the effects of "on airport" activities must in all probability be considered additional (they would not occur if the airport was not there), the same cannot be said for "off airport" activities. A significant part of these is represented, for example, by expenses incurred by tourists and businessmen reaching Florence through its airport; obviously many of them could reach Florence by other means and therefore some prudence should be used when considering "off airport" effects among the benefits (and consequently possible costs).

The evaluation of *time saved by users* is less complicated: this is the typical advantage expected from the construction or extension of a transport structure and in this case is the amount of time the present users would be obliged to employ to reach their destinations if they took a different mean of transport or used a different airport. In 1995 the amount of time saved can be estimated at 1.25 millions of hours which, using a prudent evaluation of time, is equivalent to approximately 35/40 millions of dollars yearly.

The *long-term effects* of airport development have also been seen, and have contributed to confirming that Florence is ideal as the headquarters of important multinational companies, who consider the presence of an airport an essential condition for their location, as the place for

holding exhibitions or shows (as for example in the fashion sector) or as the venue for important international political events. Here again, as in the case of "off airport" effects, it would be possible to assess the impacts of income and employment deriving from these events or companies, but we should doubtless make an error of overvaluation by attributing these elements entirely to the presence of the airport.

Still more difficult to individuate and even more difficult to quantify are the positive location effects, in other words, the decision of firms to locate their operations in the Florentine area after evaluating its facilities in terms of services and infrastructures. We shall therefore only mention this element, which can, if necessary, be included in a quality assessment. However, it is worth to stress that the relation between the employment rate of qualified workers and the distance from the nearest airport is statistically significant in most of the innovator productive sectors, according to an econometric analysis carried on upon a large sample of Italian enterprises.

As regards the present effects on the environment, after first recalling that data on air pollution are not available, we give a brief summary of the *estimated effects of noise pollution*; logically speaking, these effects are comparable to those referred to earlier as "short term", in the sense that they appear immediately air traffic starts and cease just as soon as flights are suspended.

As far as the methodology is concerned, it should be recalled that in the studies undertaken (Fisica Ambientale, 1995), reference is made to a unit of measure known as Ldn which has been adopted bearing in mind that the type of aircraft used in Florence can be classified into two uniform groups: the new generation turboprops (ATR 72, DASH8, SAAB SE340) and regional jets (BAE 146 and similar).

From estimates carried on, based on 1995 traffic, the "limit" isophonic curve, which comprises areas exposed to a noise level of over 65 dB (A) (theoretically incompatible with residential use), includes a band which extends for approximately one kilometre starting from the top end of the take-off runway. At the present time only stores and factories - and no living quarters - are located in this area; on the contrary the 63 dB (A) isophonic curve borders on a small residential area.

On the basis of indications given so far, an attempt can be made to evaluate the forecast effects of further growth of airport activity. Referring to figure 6, we consider that an average growth scenario (hereafter called scenario I) would be one of approximately 2 million passengers, while an upper limit scenario would be in the region of 3 million passengers (scenario II) and would obviously not be sustainable by the present airport unless radical restructuring and expansion work were undertaken.

Taking these two development hypotheses as a reference, we shall proceed to verify the elasticity of the above described effects and to indicate the future operation and investment costs as well as revenues (Damiani 1997).

Regarding the *economic impact* of airport company operations, we can assume that traffic growth will lead to a partly continuous and partly discreet expansion of the company, but it is easy to see that this expansion will be less than proportional to passenger growth. On one side there is a fixed employment quota, while on the other, economies of scale are to be expected for the variable component. On the basis of these considerations (using as a reference other airports and the recent evolution of Florence airport) we can get the following estimate (Table 3).

Table 3 GENERAL FEATURES OF THE GROWTH OF FLORENCE AIRPORT  
Employment in units, other variables in millions of dollars - Year 2010

	Scenario I	Scenario II
Passengers	2.000.000	3.000.000
Investment costs	78.6	123.4
Operation costs	26.8	39.3
Revenues	36.5	52.6
Balance	9.7	13.3
Amortization	7.3	11.5
Net balance	2.3	1.8
Direct employees	1.350	1.650
Activated employees "on airport" *	1.560	1.910
Activated employees "off airport" *	12.300	14.000
Activated value added "on airport" *	94	106.7
Activated value added "off airport" *	492.7	560

\* Effects in Tuscany



Slightly different considerations must be made with regard to time saving: if, in fact, the increase of supply takes place not only because of an intensification of present flights, but also because of an extension to the network (an increase in the regional jets' useful range of action is anticipated over a period of ten to fifteen years), the average amount of time saved by each passenger should increase. Quantitatively, it is estimated that application of the model would save 3.3 millions of hours in scenario I and 5 millions of hours for scenario II for a corresponding value respectively of 89 millions of dollars in scenario I and 133 millions of dollars yearly in scenario II.

With regard to the growth of *noise pollution* in the two scenarios, reference should again be made to the previously mentioned study (Fisica Ambientale 1995), in which an estimate of the growth of the isophonic curves has been made in relation to the increase in air traffic. On the basis of these indications, the increase in noise impact for the two scenarios can be assessed as follows:

Table 4 NOISE IMPACT OF FLORENCE AIRPORT

	1995 Situation	SCENARIO I	SCENARIO II
<i>Without change of procedures</i>			
increase dB(A)	-	+4	+6
involved inhabitants (n°)	139	2.156	3.789
of which:			
- over 70 dB(A)	0	0	330
- from 65 to 70 dB(A)	139	2.156	3.459
<i>With change of procedures</i>			
increase dB(A)	-	+1	+2
involved inhabitants (n°)	46	330	522
of which:			
- over 70 dB(A)	0	0	0
- from 65 to 70 dB(A)	46	330	522

The extension of the noise effect would, therefore, be quite considerable already in the first scenario, since an increase of 4 dB(A) would expose an entire residential area of about 2.000 inhabitants to a noise level of 65 dB(A) for which steps would certainly have to be taken to protect or compensate them. The second scenario would lead to a significant extension of the area involved to noise levels of 65 dB(A), as well as to an increase of the noise level over 70 dB (A) on a part of the residential area, necessitating even greater intervention to protect the inhabitants.

It should, however, be considered that there are various ways of intervening on noise impact; anti-noise barriers can be installed on the ground or, more effectively, operation procedures (take-off and landing gradients) can be modified to reduce impact. These modifications should reduce impact by approximately 3-4 dB(A) with a corresponding decrease of the involved area.

#### 4.3. The effects on Florence urban area

With the aim of introducing the assessment of the impact of Florence airport into a pattern of sustainable urban development, we must trace our analysis on the lines of a smaller-than-regional territorial scale, as represented by the Florentine metropolitan area comprised by Florence-Prato-Pistoia.

The effects of present and forecast air traffic, for which the impact of "on airport" activities has been estimated quantitatively in the previous paragraph, regard the Florentine area with the following intensity (Table 5).

Naturally the effects of employment and income produced by the airport as well as most of the long-term social and economic effects (productivity, competitiveness and location) on the local economic system (and which by their very nature we are only able to express in qualitative terms) are concentrated in the Florentine area. But although they are impossible to quantify, it should not be forgotten that these represent the most important aspect of community benefits, as widely maintained in literature.

Table 5 ECONOMIC AND ENVIRONMENTAL EFFECTS IN THE FLORENTINE METROPOLITAN AREA

	1995 situation	Scenario I	Scenario II
Satisfied demand (passengers p.a.)	800,000	2,000,000	3,000,000
Activated employees (n°)	461	951	1165
Activated added value (millions of dollars)	29.1	64.8	73.7
Time saved (millions of dollars)	7.2	15.9	24.0
Noise pollution (n° of inhabitants)	139	2.156	3.789
Rush hour traffic (n° of vehicles)	400	1.035	1.530

Lastly, regarding environmental effects, it is possible to assess also the incidence of the growth of air movement on ground traffic. The number of vehicles to and from the airport currently amounts to approximately 400 units during the rush hour. This value, taking into account the distribution of users between public transport and passengers' and employees' cars, should increase to over 1,000 units in scenario I and over 1,500 in scenario II (Damiani, 1997). If the present airport-linked traffic on the surrounding road network (access to motorway and trunk roads) may be considered of little significance, in the two above hypotheses it will certainly give rise to congestion (the airport rush hour coincides with that of the city), unless relevant investments are made in this sector.

#### 4.4. A hint on long term effects

As already noted, in the long term the operation of an airport is able to produce effects both in terms of productivity and location of new activities. The empirical evaluation of this impact is always hard, owing to the difficulty of isolating the effect of this infrastructure from those of other economic or social factors. As a consequence, we need to look for indirect signs of this relationships, for instance verifying the location choice of the firms (and their typology) around the airports.

From a large sample of Italian private firms (with more than 20 employees), clustered according to the distance from an airport, it can be verified that almost the half (48%) of the employees of "export oriented" (and even more innovative) enterprises are located within an area of 20 kilometres from the airport, while the same percentage, as far as the others are concerned, is not more than 34%.

Table 6 DISTANCE FROM AIRPORTS AND MANUFACTURING FIRMS TYPOLOGY  
Percentual values

Distance Classes	< 20 km.	20-50 km.	50-100 km.	> 100 km.
<b>FIRMS</b>				
"export oriented"	38,3	33,1	22,4	6,1
others	29,6	34,9	26,6	8,9
<b>EMPLOYEES</b>				
"export oriented"	47,6	28,8	18,7	4,9
others	33,9	32,1	27,2	6,8

Analogous results can be referred to the quality of employees, that seems to be particularly concentrated in the proximity of airports (the labour cost per employee decreases when the distance of the firm from the airport is growing).

At the same time, the productivity of the firms seems also positively related (in most of sectors) to the proximity of an airport, as it can be seen from the results of an econometric estimate. In both of the estimated equations, the value added per employee has been related to the different kinds of capital (circulating capital «CC» and fixed assets «FA») as well as to the distance from an airport (weighted by means of the total number of passengers); in model A the closeness to a metropolitan area has been introduced in the evaluation, while in model B the difference between the regional productivity and the national one in each sector is estimated.

Other functional forms have also been tested, even including all the quoted variables, but without significant improvements in the evaluation.

As a consequence, even if the results cannot be considered as definitive, we can assume, according with other authors (see Butler-Kierman 1986), that airports are "magnets" which attract economic enterprises, innovation processes, skilled employees, in other terms pre-conditions for the economic growth.

Table 7 PRODUCTION FUNCTION ESTIMATE  
 $V_{A_e} = f(CC_e, FA_e, AD, CD, RD)$

Productive Sectors		Adj R <sup>2</sup>	CC <sub>e</sub>	FA <sub>e</sub>	AD	CD	RD
ALIMENTARY FOODS	A	31.9	0.427 (**)	0.232 (**)	-0.064 (*)	0.073 (*)	
	B	32.6	0.422 (**)	0.227 (**)	-0.029 N.S.		0.107 (**)
TEXTILE	A	32.6	0.435 (**)	0.280 (**)	-0.101 (**)	0.042 N.S.	
	B	34.1	0.424 (**)	0.294 (**)	-0.064 (*)		0.127 (**)
CLOTHES	A	50.8	0.526 (**)	0.301 (**)	-0.044 N.S.	-0.002 N.S.	
	B	51.4	0.517 (**)	0.294 (**)	-0.045 N.S.		0.080 (*)
LEATHER AND FOOTWEAR	A	52.1	0.542 (**)	0.278 (**)	-0.059 (*)	0.018 N.S.	
	B	52.1	0.536 (**)	0.281 (**)	-0.050 N.S.		0.029 N.S.
WOOD PRODUCTS	A	45.4	0.524 (**)	0.297 (**)	-0.012 N.S.	-0.086 N.S.	
	B	47.4	0.514 (**)	0.269 (**)	-0.041 N.S.		0.160 (**)
PAPER PRODUCTS	A	30.0	0.409 (**)	0.257 (**)	-0.107 (*)	0.096 N.S.	
	B	31.1	0.392 (**)	0.274 (**)	-0.103 (*)		0.139 (*)
PUBLISHING INDUSTRY	A	32.2	0.416 (**)	0.250 (**)	-0.169 (*)	0.097 N.S.	
	B	32.7	0.405 (**)	0.250 (**)	-0.070 N.S.		0.109 (*)
CHEMICAL AND PHARMACEUTICAL	A	26.9	0.445 (**)	0.176 (**)	-0.087 N.S.	0.041 N.S.	
	B	27.4	0.446 (**)	0.172 (**)	-0.031 N.S.		0.083 (*)
RUBBER AND PLASTIC PRODUCTS	A	28.8	0.372 (**)	0.277 (**)	-0.076 (*)	-0.016 N.S.	
	B	29.1	0.363 (**)	0.274 (**)	-0.066 (*)		0.058 N.S.
NON METAL MINING	A	33.3	0.432 (**)	0.253 (**)	-0.004 N.S.	0.083 (*)	
	B	33.4	0.419 (**)	0.256 (**)	0.011 N.S.		0.079 (*)
MECHANICAL INSTRUMENTS	A	22.5	0.393 (**)	0.175 (**)	-0.083 (*)	0.025 N.S.	
	B	22.5	0.394 (**)	0.175 (**)	-0.065 (**)		-0.002 N.S.
FURNITURE	A	17.7	0.317 (**)	0.235 (**)	-0.032 N.S.	-0.061 N.S.	
	B	18.5	0.313 (**)	0.240 (**)	-0.051 N.S.		0.101 (*)
CONSTRUCTION AND WORKS	A	21.8	0.359 (**)	0.174 (**)	-0.044 N.S.	0.034 N.S.	
	B	21.8	0.357 (**)	0.173 (**)	-0.023 N.S.		0.020 N.S.
WHOLESALE TRADE	A	32.8	0.510 (**)	0.134 (**)	-0.120 (**)	0.025 N.S.	
	B	32.8	0.508 (**)	0.133 (**)	-0.094 (**)		0.016 N.S.
INTERMEDIARY TRADE	A	34.5	0.255 (*)	0.495 (**)	-0.149 N.S.	-0.041 N.S.	
	B	40.6	0.241 (*)	0.416 (**)	-0.218 (*)		0.264 (*)
HOTELS AND PLACES	A	49.3	0.300 (**)	0.623 (**)	-0.067 N.S.	-0.076 N.S.	
	B	49.7	0.318 (**)	0.611 (**)	-0.155 (*)		0.091 N.S.
VARIOUS SERVICES	A	40.3	0.440 (**)	0.304 (**)	-0.048 N.S.	-0.026 N.S.	
	B	40.5	0.438 (**)	0.296 (**)	-0.037 N.S.		0.053 N.S.

- (\*\*) Significant parameter 1%  
 (\*) Significant parameter 5%  
 N.S. Not significant parameter
- $V_{A_e}$  = Value added for employee  
 $CC_e$  = Circulating capital for employee  
 $FA_e$  = Fixed assets for employee  
 AD = Airport distance (weighed with total number of passengers)  
 CD = Distance from the nearest metropolitan area  
 RD = Difference in regional productivity

## 5. THE TRADE-OFF BETWEEN GROWTH AND ENVIRONMENTAL PROTECTION

### 5.1. Nature and treatment of the conflict

It is evident that the operation of an airport, in particular that of a city airport, produces both negative and positive consequences which rebound upon the subsystems which make up the city - the social system, the economic system and the physical-environmental system.

These effects, whether positive or negative, can lead to either conflictual or harmonious interrelations between the various subsystems. Let us consider, for example, the relationship between the economic and the environmental subsystems, which are those of greater interest in this case. It can be said that, in the short term, the impact of an airport is extremely positive in economic terms, while the cost to the environment is equally evident. Negative effects on the environment are spatially very circumscribed, consequently the contrast between the economic and the environmental effects is emphasized, especially at a local level. This is not to say that in the long term (and given that the traffic does not exceed technically and socially acceptable

levels) such a conflict of interests may not disappear, to make way for a positive interrelation between the two elements. In effect, an economic system strengthened by the contribution of an important traffic infrastructure such as an airport can produce sufficient resources also for investment in the interests of environmental conservation.

Therefore, if on the one hand it is true that the very idea of sustainability emerges from the necessity to reconcile the conflicting economic and environmental aspects, on the other it is useful to bear in mind that, when a trade-off between the economy and the environment is spoken of, in most cases reference is made to an only partial confrontation of consequences. The limitation of the comparison is largely due to the absence from the assessment of the long-term impact (economic, social or environmental). If this information were supplied, then the outcome of the trade-off between cost and benefit could be substantially altered.

The fact remains that, in the short-term view, the conflict between economic growth and environmental sustainability exists and can be resolved in various ways. As far as airports are concerned, experience has taught that the various methods of settling the conflict can be brought down to the alternative between an authoritative decision and a negotiation. In the first case, irrespective of the interests and the individuals involved, the presence of an airport in the urban area is upheld (or invalidated) by an authority higher than the local authority (usually a national institution). In the second case, the conflict of interests is handled within the urban area through compensatory intervention, or by the removal of injured parties, or through a regulatory system which limits the use of the airport in defence of civic rights usually promoted or run by the most representative local authority.

Upon examination of the situations of currently operative city airports, the regulation of these matters at the Toronto City Airport appears particularly restrictive. A tri-lateral agreement between the airport management, the Federal Department of Transport and the Toronto Municipal Corporation, prohibits the use of the airport by jets. This limitation has caused a progressive decline in traffic (-50% in 8 years) exacerbated by the economic difficulties provoked by over-limited traffic. Here we are dealing with a *categorical limitation* (ban on the use of regional jets) even though the supporters of the airport maintain that the atmospheric pollution produced by jets would still be inferior to that at just 5 kilometres of the surrounding road network. More predictable results are certainly obtained through limitation based on the principle of *quota imposition*, or the pre-determination of a maximum number of passengers, or rather a maximum number of aircraft movements, considering that these are more easily programmed and that they are directly linked to the environmental effects of the airport.

More frequent are models of the *statutory type* (rules governing procedures for take-off, landing, ground manoeuvres and monitoring) which are in some cases imposed by the aviation authorities, while in others they emerge from negotiations between the local authorities and the airport management, as a result of solicitation by lobbies demanding greater control over environmental consequences. The Noise Management Scheme adopted by the London City Airport is of this type. It provides a specific training in the procedures for the pilots, and the constant monitoring of the acoustic impact, as well as a penalty system for the airlines every time the standard noise levels of the different types of aircraft are exceeded (beyond a certain limit).

The regulation of procedures for Florence airport will derive from an agreement (currently under approval) between the Minister of Transport, the airport management and the local authorities of the metropolitan area. The regulation stipulates the overnight closure of the airport (from 10.45 p.m. to 7.00 a.m.), provides the one-way use of the runway and defines the approach and exit airways from the flight runway.

## 5.2. Synthetic evaluation of the consequences

There are many ways of evaluating the comparison between the positive and negative consequences of a traffic infrastructure, for the purposes of territorial planning. As we know, the main ones are the cost-benefit approach and multi-criteria analysis. Every time that a monetary evaluation of the positive consequences seems possible, and that an economic compensation for a negative consequence is made (or even conjectured), then we have a justification for applying a cost-benefit analysis.

Naturally, there are limits to economic compensation; although these are indefinite and vary in time, they are still such as to create an upper limit to the practicality of financial compensation. In the case of a working airport, for example, the most widespread response to the alleviation of the noise effect is the sound-proofing of the nearby habitations which, although it has limits (it does not completely solve the problem) at least partially attenuates the

damage. Obviously, such compensatory action (and to a greater extent the removal of numbers of residents in noise-affected areas to other areas) can be considered a solution compatible with the concept of sustainable development only if the number of persons is limited. This would not be the case if entire districts of the city were involved. The cost of sound-proofing the noise-affected properties, however, still remains a widely-used estimate of the cost of acoustic pollution, even though one could also use the loss on market value of the properties themselves (hedonic price method, see Quinet 1996).

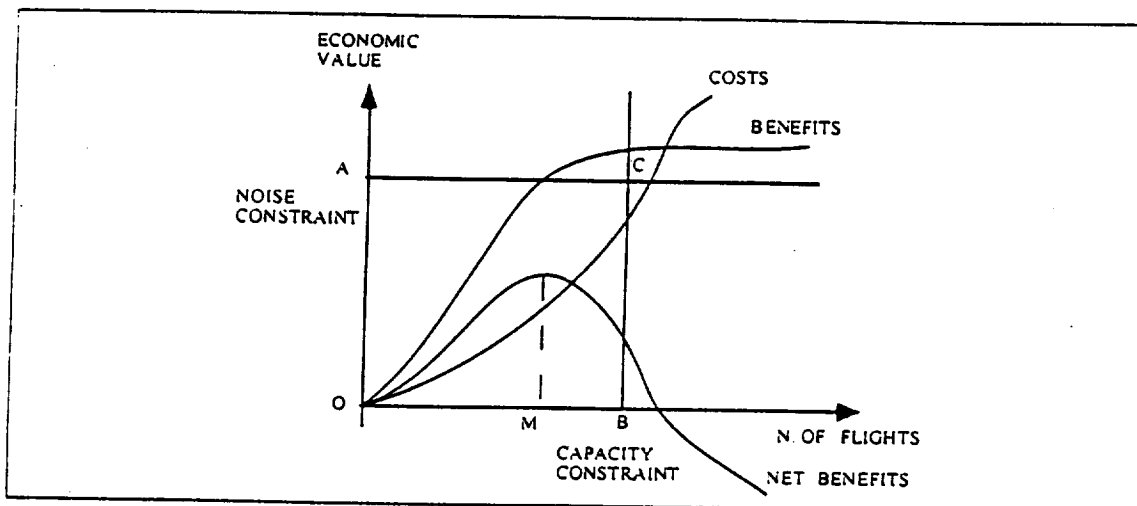
According to Pearce and Markandya the depreciation of house price can be estimated in 0.5% (at the increase of one unit of change in the level of constant sound in  $dB_{(A)}$ ) for some cities of the U.S.A., while in Switzerland the decrease of the value can exceed the 1.00% (Basel 1.26%).

In this paper we limit ourselves to the comparison of the benefits and the costs bearing on the activity of the Florence airport, without executing a real cost-benefit analysis. As will become clearer further on, we must also bear in mind, not only that the measurable consequences are not the only ones, but also that the trade-off analysis can only have meaning within a field of action which is limited simultaneously by the maximum acceptable level of acoustic pollution, and by the maximum physical potential of the present airport structure.

### 5.3. An attempt to formalise the trade-off

The following diagram represents the factors and the restrictions related to the method for determining the level of airport activity most compatible with the requirements of a sustainable urban development.

Figure 7 THE OPTIMAL LEVEL OF AIR TRAFFIC



The abscisse represents airport activity through the number of flights per time unit; the ordinate bears the economic evaluation of the benefits and of the environmental consequences. We have already mentioned the valuation method used for the benefits, while for the environmental effects (referring exclusively to acoustic effects) the procedure generally employs the cost of mitigation of these same effects. These consequences, however, can be compensated only within a definite limit (equivalent to the sound-proofing of a number of dwellings or to the assisted removal of a certain number of inhabitants). This limit (which we can refer to as "noise constrain") has the nature of *social acceptability* depending on the people's sensitivity or, in other terms, on the prevailing scale of social preferences.

There is, however, another limit to the definition of a sustainable traffic level, which is the maximum production range of the airport itself. With a view to defend unrenowned resources such as space (which in the case of a city airport is, generally speaking, an extremely limited resource within the urban area) we may assume that it is impossible to extend the airport area by an expansion of its potential. A consistent increase in the airport's potential would, moreover, implicate not only additional space (both paved and unpaved), but also other additional resources such as energy and water. This element constitutes the second limitation (by its nature defined "capacity constrain") which is essentially that of technical *sustainability*.

Once the variables and the boundaries of the sustainable level (rectangle OACB) have

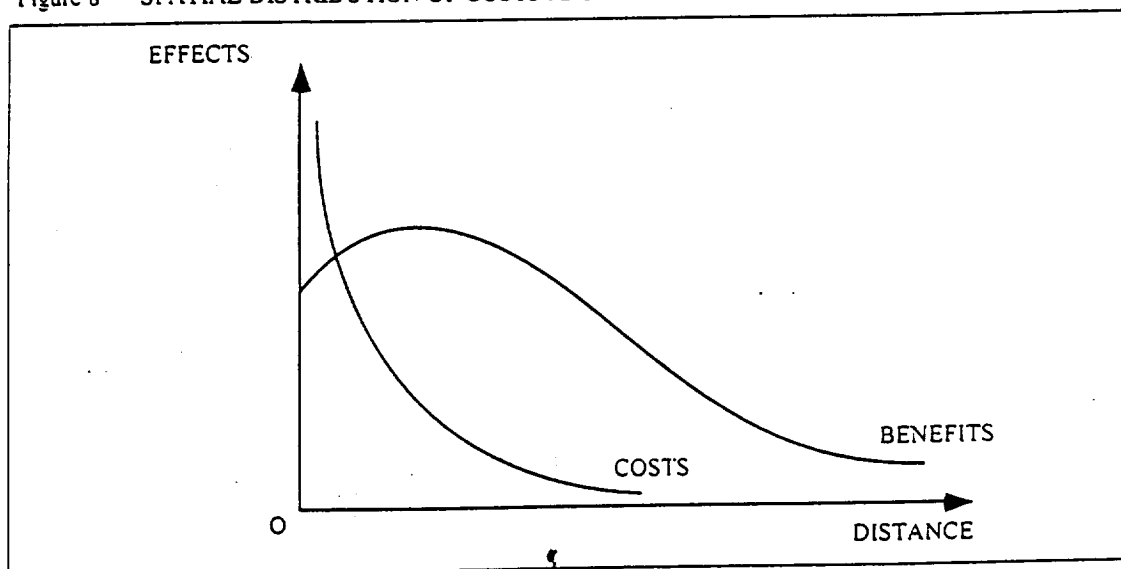
been determined, one can attempt to define what is the "optimum" number of flights, that is which would allow the maximum net benefits while respecting a pre-determined level of urban sustainability. Supposing that the cost and benefit curves follow the tendencies represented in the graph (which would appear to fit the case of a city airport with benefits superior to costs within certain limits, slightly concave benefit curve, convex costs curve), then a level of airport activity equivalent to M number of flights assures the greatest gain relative to net social benefits, whilst respecting environmental restrictions.

## 6. THE SPATIAL SCALE OF REFERENCE

Prior to the analysis of the trade-off between economic and environmental consequences, another important aspect to be considered is the definition of the spatial scale of reference. We have already hinted at this aspect with reference to the various categories of effects. The economic effects (positive) tend to extend outside the city, involving, although to a diminishing degree, the region and the rest of the country. The environmental effects, especially if we limit consideration to that of acoustic pollution, are instead concentrated within the urban area surrounding the site of the airport (Figure 8).

This situation is not necessarily inevitable. There are, in fact, circumstances which provoke an irregular distribution of the marginal negative consequences as regards the distance from the point of realisation, or, more generally, where the intervention marginal costs are higher further from the source than in the immediate surroundings.

Figure 8 SPATIAL DISTRIBUTION OF COSTS AND BENEFITS: HYPOTHESIS 1

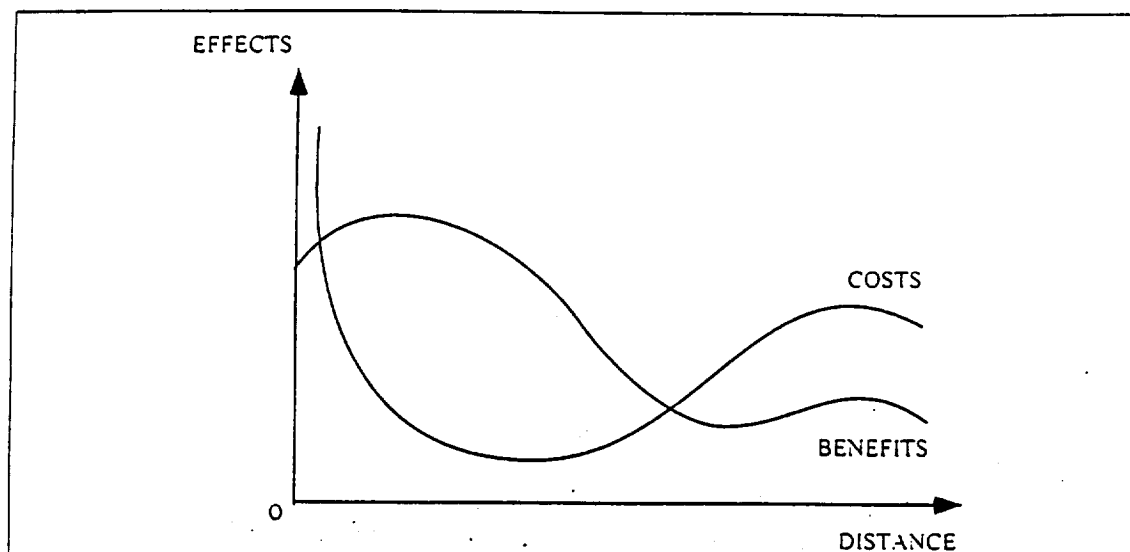


With reference to the case of airport location, one might suppose that a decision in favour of a city airport, supported by a conventional airport at a more distant location, would relegate the negative effects of the second structure to an area distant from that in which the strategic decision was taken. In fact, the option of channelling all the air traffic from an urban area to a single large airport 10 or 15 kilometres from the city centre would effectively concentrate the greater part of the negative effects within the metropolitan area. Whereas the decision to divide the air travel demand between two specialised airports (one close to the centre for business traffic, and one considerably more distant for the remainder of the traffic) would remove the greater part of the environmental costs from the metropolitan area. The situation could be represented by the following figure 9.

From the comparison of these curves we may deduce that it is not always correct to verify only the urban sustainability of a project, if this is able to provoke overflow spillover effects towards areas external to that in which the decision is taken.

Sustainability within the urban area is therefore an essential, but not always sufficient, condition for a positive decision on the acceptability of a project. The territorial dispersion of the consequences beyond the urban area could, according to the principles of fiscal federalism, extend the authority for a definitive decision to a wider level.

Figure 9 SPATIAL DISTRIBUTION OF COSTS AND BENEFITS: HYPOTHESIS 2



## 7. CONCLUSIONS

The analysis carried out in this paper, with reference to the growth of Florence airport, appears to constitute an useful way to verifying the relationship between infrastructure endowment and the economic growth on one hand, and to testing the trade-off between city marketing and environmental protection on the other.

Few tentative conclusions might be summarised as follows:

a) Florence airport appears to be particularly strategic, given the international role of the city and its ambition to participate competitively with other European urban areas, even if, obviously, its presence must be considered more as a necessary, but not sufficient, condition.

b) At a relative high level of economic development of a country the demand seems to be the driving element to induce the airport investments. The benefits for the users as well as for the firms are really substantial, even if the availability of empirical evaluation are more uncertain as far as the long term effects are concerned.

c) Traditional cost benefit analysis tends -in cases like this one- to extend the use of the economic evaluation tools to factors which are not economic. It does not take into consideration the acceptability limits (from social system) and the sustainability limits (from environmental system) which often -at their adequate spatial scale of reference- constitute unsurmountable restrictions.

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**Topic Area:** C3

**Authors:**

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**Title:**

NOISE AND AIR QUALITY VALUATIONS: EVIDENCE FROM STATED PREFERENCE RESIDENTIAL AND BUSINESS CHOICE MODELS

**Abstract:**

This paper reports the results of a study which aimed to improve understanding of the relationship between land use and transport. In this paper we present empirical research undertaken to investigate the influence on land use and location choice of the transport related environmental indicators, air quality and noise. The work involved a computerised survey including attitudinal and qualitative questions regarding environmental, accessibility and location issues and a stated preference exercise offering trade-off between noise levels, air quality levels, car accessibility, bus accessibility and local residential taxes. A large scale survey of 400 households in Edinburgh was undertaken and a smaller exploratory study of local businesses.

The paper focuses on the monetary values of air quality and noise obtained and the various methodological issues raised, for example, different ways of presenting air quality changes to respondents, the comparative effects of equivalent improvements and deteriorations in environmental quality and how the stated preference results compare with the valuations obtained from willingness to pay statements and with various attitudinal indicators.





Topic Area: C3

**NOISE AND AIR QUALITY VALUATIONS: EVIDENCE FROM  
STATED PREFERENCE RESIDENTIAL AND BUSINESS CHOICE MODELS**

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## **1 INTRODUCTION**

It is increasingly recognised that the relationship between land use and transport planning is crucial to the development of sustainable integrated policies for cities. However, understanding of the impacts of transport policies on location choice and land use is limited (Still, 1997). This paper reports on one aspect of a study funded by the Engineering and Physical Sciences Research Council undertaken by the Institute for Transport Studies in collaboration with The MVA Consultancy and the David Simmonds Consultancy, which aimed to improve understanding of this relationship. The principal objectives of this study were:

- (i) to increase our understanding of the impact of accessibility and environmental quality on individuals' and firms' location decisions;
- (ii) to use the findings of (i) to enhance a newly developed strategic transport and land use interaction model;
- (iii) to use the enhanced model to assess the implications for urban sustainability of the impact of transport policy on location choice;
- (iv) to use the enhanced model to assess the relative performance of different combinations of transport and land use strategy.

The research fell into two main categories; the survey work and analysis undertaken to increase our understanding of the influence of environmental and accessibility factors in location choice and the other main strands of work relating to model enhancement and strategy testing, reported in a companion paper (Bristow et al, 1998). The focus of this paper is on the valuation of environmental attributes. In the next section we discuss the development of our methodology and the survey implementation. Sections 3 and 4 examines the results in terms of perceptions and attitudes and also the outcome of a willingness to pay question. Sections 5 and 6 contains the main analysis and results of the household and business stated preference surveys. Concluding remarks are provided in Section 7.

## **2 DEVELOPMENT OF THE METHODOLOGY**

Our aim was to obtain values of transport related environmental impacts that would be relevant to location choice. Therefore, we needed individual or household values for specific locations. The existing evidence on environmental values does not in the main reflect UK specific values and does not necessarily reflect current preferences (Tinch, 1995, Mauch and Rothengatter, 1995, Maddison et al 1996 and Perkins 1997 all provide reviews of the evidence).

The data for estimating the monetary valuations of environmental quality and accessibility were obtained from a large scale survey of households and a small scale, exploratory survey of firms in Edinburgh.

## 2.1 Survey Design

The sample for the residents' survey was drawn from areas in the south west, south and south east of the city. These areas were chosen because the journey into the centre of town in off-peak conditions from any of them would take longer than ten minutes by car. In these areas a number of streets were chosen to be included in the survey. The streets were selected to represent both residential and those carrying through traffic. It was assumed that these types of street would carry both high and low volumes of traffic and could therefore give a range of actual measurements and perceptions of traffic noise and air pollution.

Measurements of Nitrogen Dioxide (NO<sub>2</sub>) in the air in  $\mu\text{g}/\text{m}^3$  were taken at a mixture of junctions and mid-link on both arterial and residential streets. The traffic noise measurements were taken at both mid-block and junction locations at house facades rather than on the roadside. The NO<sub>2</sub> measurements were taken over a week period and the measurements for noise were taken over an 18 hour period. Each reading for noise or NO<sub>2</sub> was matched with the appropriate interview. This meant that for a selection of the interviews the perceptions of noise and air quality could be matched with an objective contemporaneous measurement.

The businesses were selected because they were in the city centre and because it was possible for employees at the firm to park very close, if not outside of the actual office. This allowed the Stated Preference design to offer trade-offs between increases in the walking journey from the parking location and improvements in the air and noise quality at the office. The businesses included in the sample were also chosen because they had control over where they were located. This meant that many branch offices of larger firms were not included. The sampling technique also excluded retail outlets but included many service providers for example, solicitors firms, computer software houses, marketing and public relations consultants.

Households' and firms' preferences amongst different levels of environmental quality, accessibility and monetary outlay were established using a Stated Preference (SP) exercise. Comparable analysis of actual decision making would have required the collection of a very large data set and would face the problem of isolating the effect of attributes which are of interest to this study from attributes specific to particular houses or offices. The advantage of the SP approach is that it can control what is evaluated by individuals and the SP exercises used here exploit this feature by specifying that the alternatives being considered differ solely in respect of their accessibility, environmental and cost characteristics.

For households, the SP exercise offered choices between the different house location characteristics of air quality, noise levels, car accessibility, bus accessibility and the level of council tax. Accessibility was defined solely in terms of inter-zonal journey times. The SP exercise for firms was similar but with business rates replacing the council tax whilst accessibility was based on walking times to and from the office.

In addition to the SP exercise, a number of questions were asked about the composition of the household or company, current trip making by car and bus, current environmental and accessibility conditions, and attitudes towards and the sources of noise and air pollution. Willingness to pay questions relating to improvements in noise levels and air quality were

also asked and the valuations can be compared with those obtained from the SP exercise. The survey was administered as a home or office interview using portable computers.

## 2.2 Household SP Design

Sixteen pairwise comparisons were offered to an adult household member who was asked to respond in terms of the household's preferences. Alternative B was generally associated with improved accessibility and environmental quality but had a higher weekly council tax. A fractional factorial orthogonal plan was used to construct the combinations of environmental quality and accessibility differences between the two alternatives. The cost differences were originally taken from an orthogonal plan but were subsequently amended to provide a better range of trade-offs without introducing unduly large correlations.

The accessibility and environmental variables took four levels each. In part this was so that we could enter at least one level as a zero difference between alternatives to simplify the task of comparing alternatives. As a result, at least one variable was the same for each alternative in all but two of the comparisons. In addition, we were concerned that the environmental variables, which might have relatively low values compared to accessibility, were not dominated and thus two of the four accessibility levels for both car and bus were specified to be the same for each alternative. This resulted in four scenarios where the trade-off was simply between environmental quality and money and only four scenarios where both accessibility variables differed between the two alternatives.

The levels of the environmental quality and accessibility variables are given in Table 1. The levels were generally specified as proportionate changes to the current conditions (C). Although this means that orthogonality will not be maintained, the correlations which would be introduced were not expected to be a cause for concern. The two terms denote the level of a variable for each alternative and thus C:-50 denotes that alternative A at its current level and alternative B is 50% better than the current level. A feature of our design which is apparent from Table 1 is that we wished to examine whether an improvement up to the current position, such as +50:C, is valued the same as an improvement from the current position, such as C:-50. For each level, one form of difference was randomly selected and presented to the individual each time that level arose. A similar procedure was adopted for cost except that whether the monetary variation formed an increase up to the current level of council tax or an increase upon it was randomly distributed across all the sixteen comparisons.

Table 1: Levels of Variables in Household Design

	Car Time	Bus Time	Noise	Air	Air
0	C:C	C:C	C:C	C:C	C:C
1	C:C	C:C	C:-50 +50:C	C:-50 +50:C	Worst:C
2	C:-10 +10:C	C:-20 +20:C	+100:C C:-100 +50:-50	+100:C C:-100 +50:-50	C:Best
3	C:-20 +20:C	C:-33 +33:C	+100:-100	+100:-100	Worst:Best

Variations in the car and bus in-vehicle times related to trips from the respondent's home zone to each of the other zones in Edinburgh. The 15 zones were shown on a map and the respondent stated the expected car and bus journey times between the home zone and each other zone and also the number of trips made by members of the household by each mode. Proportionate changes were offered both for realism, since general improvements or

deteriorations to travel conditions can be expected to have a different effect according to the length of the journey, and also to facilitate modelling opportunities since the absolute time changes would vary across different inter-zonal movements and therefore could be analysed separately if so wished.

One of the main difficulties in valuing environmental variables within SP exercises is that of adequately representing the variables given that there is no measurement scale that can be readily used. Respondents can hardly be expected to relate to decibel scales or some measure of air quality such as parts per million of carbon monoxide in the atmosphere.

The two approaches we considered were based on location specific descriptions and percentage changes. The latter has been used in environmental valuation studies (Sælensminde and Hammer, 1994), and its usefulness is increased if a measure is taken of the base from which conditions are specified to vary. The former approach involves offering individuals different locations containing the desired level of environmental quality which are then compared alongside the current situation.

We have compared the two presentational methods for air quality. Respondents were offered 5 locations with very bad air quality and 5 locations with very good air quality and were asked to select one of each, denoted Best and Worst, which were compared with each other and the current situation as depicted in Table 1.

We did not pursue the location specific method for noise on the grounds that we felt that the respondents' familiarity with noise levels in other locations would largely be related to outdoor noise which is not readily comparable with that experienced indoors. Where respondents informed us that their air quality or noise levels were good, we did not offer improvements.

Simulation tests were conducted on the statistical designs using synthetic data. This was an iterative process involving several amendments to the design until satisfactory estimates could be recovered across a range of monetary valuations of the four variables. Indeed, it was this series of tests which led us to depart from orthogonality for the cost variable.

### **2.3 Business SP Design**

We interviewed a senior company representative who was involved in location decision making and sixteen pairwise comparisons were offered described in terms of walk times to and from the office, air quality, noise levels and business rates.

The same general procedure was adopted as for the household survey. The walking and environmental quality variables were combined according to a fractional factorial design. The business rates were varied from the levels required for orthogonality to introduce more sensible trade-offs. This was again shown to be desirable as a result of a simulation test procedure.

Table 2 lists the levels of the non monetary variables. Given that there was only one accessibility variable, it was considered that there was less of a need to have two levels where there was no difference between alternatives. The walk time variations were introduced by

specifying pedestrianisation of the area around the office such that walking times to and from car parks and bus stops increased by on average 2, 5 or 8 minutes. It was not feasible to offer improved levels of walking times.

Table 2: Levels of Variables in Business Design

	Walk Time	Noise	Air
0	C:C	C:C	C:C
1	2:C	C:-50 +50:C	Worst:C
2	5:C	+100:C C:-100 +50:-50	C:Best
3	8:C	+100:-100	Worst:Best

Given the small sample size, it was decided to concentrate on the location specific method of presenting air quality. Noise entered in the same fashion as for the household survey and the same procedure for presenting the different variations within each level was used. The differences in business rates, of either increases up to current levels or increases upon current levels, were again randomly varied across all sixteen scenarios.

### 3 PERCEPTIONS AND ATTITUDES

In this section we examine the responses of households and businesses to questions about their environment, the presence of any problems and what their priorities are for improvements. The sample size used for the household survey is 403 and for the business survey 26 (except where otherwise stated). Table 3 shows the response of households to a scale asking about general noise affecting the household in and around the house and air quality. It can be seen that 38.7 % of respondents felt that their local area was noisy or very noisy, rising to 65.5% including the category quite noisy, while only 9.2% felt that their area was quiet or very quiet. In contrast 32.5% of respondents felt that the air quality was poor or very poor, with 34.5% saying the air quality was good or very good. It would appear from Table 3 that noise is perceived to be the greater problem in the areas surveyed. The figures for businesses suggest that neither noise nor air quality are perceived to be particular problems for the majority of the sample. The analysis reported in Section 5 segments the SP models according to current reported conditions.

Table 3: Household Perceptions of Local Noise and Air Quality

Noise			Air		
Very Noisy	85	(21.1%)	Very Poor	32	(7.9%)
Noise	71	(17.6%)	Poor	99	(24.6%)
Quite Noisy	108	(26.8%)	Fair	137	(34.0%)
Fairly Noisy	102	(25.3%)	Good	106	(26.3%)
Quiet	20	(5.0%)	Very Good	29	(7.2%)
Very Quiet	17	(4.2%)			

Respondents were asked to give the three most important causes of noise and air pollution in their area and the responses are shown in Tables 4 and 5. The category no noise/no reason in table 4 includes those who said their area was quiet or very quiet, who were not asked this question and those who did not give a reason. Table 4 shows that by far the most commonly mentioned cause of noise was traffic, with 79.1% of the total sample reporting this as the

most important cause and 87.6% mentioning it as one of the three most important causes. However, other causes were also recognised, including people and children outside and neighbours and other transport sources such as planes and trains.

Table 4: Households: Causes of Noise (percentages in brackets)

Cause	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	% mentioning
No Noise/No Reason	39 (9.7%)	160 (39.7%)	253 (62.8%)	-
Road Traffic	319 (79.1%)	24 (5.9%)	10 (2.5%)	87.6%
Aircraft	14 (3.5%)	64 (15.9%)	16 (4.0%)	23.3%
Children Playing Outside	10 (2.5%)	37 (9.2%)	19 (4.7%)	16.4%
People Outside	7 (1.7%)	62 (15.4%)	39 (9.7%)	26.8%
Trains	6 (1.5%)	16 (4.0%)	17 (4.2%)	9.7%
Factories	0 (0.0%)	6 (1.5%)	3 (0.7%)	2.2%
Building Work	0 (0.0%)	7 (1.7%)	17 (4.2%)	5.9%
Neighbours	6 (1.5%)	18 (4.5%)	15 (3.7%)	9.7%
Other	2 (0.5%)	9 (2.2%)	14 (3.5%)	6.2%

In Table 5 the category no poor air/no reason includes those who rated their air quality to be good or very good, who were not asked this question and those who did not provide a reason. For air quality this category is more common than for noise. However, where people do recognise a cause, road traffic is overwhelmingly seen as the main cause. This is also the case for the business sample, where all those who listed a cause gave road traffic as their first choice.

Table 5 Households: Causes of Air Pollution (percentages in brackets)

Causes	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	% mentioning
No Poor Air/No Reason	137 (34.0%)	299 (74.2%)	353 (87.6%)	-
Road Traffic	250 (62.0%)	14 (3.5%)	4 (1.0%)	66.5%
Trains	0 (0.0%)	25 (6.2%)	6 (1.5%)	7.7%
Specific Local Source	4 (1.0%)	14 (3.5%)	7 (1.7%)	6.2%
Factories/Industry	4 (1.0%)	33 (8.2%)	12 (3.0%)	12.2%
Other	8 (2.0%)	18 (4.4%)	21 (5.2%)	11.7%

Table 6 shows the results obtained using a rating scale from 0 to 100, where 0 represents no disturbance from traffic noise and 100 represents very serious disturbance from traffic noise. The mean, standard deviation (SD) and standard error (SE) are reported along with various percentiles. The conditions reported are for current noise levels, twice the present level and half the present level. Current noise levels show a mean of 41, suggesting that on average noise is not a serious problem. However 10% of the sample gave a rating of more than 80% indicating that they suffer serious disturbance. When respondents considered noise levels twice as high, 25% gave a ranking of 99 or above, suggesting that they wished to go beyond the end of the scale to reflect the problem, which may go some way to explaining why the score does not double. There are still a number of respondents for whom noise would not be



a problem. A halving of noise levels leads 25% of respondents to push their score to a zero indicating no disturbance.

Table 6. Households: Noise Level Ratings

	Mean	SD	SE	10%	25%	50%	75%	90%
Current Noise	41	26	1.3	9	19	39	60	80
Twice as Bad	68	28	1.4	25	50	71	99	100
Half as Bad	19	19	0.9	0	0	15	34	50

Table 7 is the equivalent table for air quality. Interestingly the scores here are generally higher than for noise in a slight contradiction of Table 3. However, the two are not strictly comparable as Table 7 contains a question asked of only half the sample, giving a sample size of 200. The pattern when asked about change is very similar to that for noise.

Table 7 Households: Air Quality Ratings

	Mean	SD	SE	10%	25%	50%	75%	90%
Current Air Quality	45	30	2.1	5	14	50	70	88
Twice as Bad	70	30	2.1	20	50	80	100	100
Half as Bad	20	23	1.7	0	0	10	40	50

Respondents were also asked about actions they might have taken to reduce the impact of noise and their priorities for improvements in the area. The majority of households reported no action or double glazing installed by a previous occupant or for other reasons. However, around 20% of households had installed double glazing with the aim of reducing noise levels and a small proportion had installed or altered hedges and fences to reduce noise impacts. Table 8 shows the responses of households to a question asking their three most important priorities for improvements. The most frequently mentioned first choice was road safety, the next four were very closely bunched and included improved air quality, lower council tax, reduced noise levels and reduced crime. The same five items are those receiving the most mentions overall. Hence, it would seem that air quality and noise levels are important factors in local quality of life. The list offered to business respondents was somewhat different and showed the main concerns to be the business rates, congestion and parking provision.

Table 8: Households: Three Most Important Priorities for Improvement  
(percentages in brackets) (sample size 353)

	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	%mentioning
Improved Road Safety	85 (24.1%)	47 (13.3%)	37 (10.5%)	47.9%
Reduced Local Crime	46 (13.0%)	42 (11.9%)	33 (9.3%)	34.3%
More Local Play Facilities	22 (6.2%)	34 (9.6%)	32 (9.1%)	24.9%
Improved Air Quality	51 (14.4%)	54 (15.3%)	31 (8.8%)	38.5%
Improved Health Care	12 (3.4%)	18 (5.1%)	29 (8.2%)	16.7%
Reduced Noise Levels	48 (13.6%)	55 (15.6%)	43 (12.2%)	41.1%
Improved Local Appearance	13 (3.7%)	25 (7.1%)	25 (7.1%)	17.8%
More Local Shops	14 (4.0%)	31 (8.8%)	27 (7.6%)	20.4%
Improved Education Quality	12 (3.4%)	15 (4.2%)	26 (7.4%)	15.0%
Lower Council Tax	50 (14.2%)	32 (9.1%)	70 (19.8%)	43.0%

#### 4 WILLINGNESS TO PAY FOR NOISE AND AIR QUALITY IMPROVEMENTS

In addition to the valuations that can be estimated from the responses to the SP exercise, (Sections 5 and 6) a set of questions was asked at the end of the interview concerning the willingness to pay additional council tax in return for reductions in noise levels or improvements in air quality. Respondents were asked about the household's willingness to pay for a halving of noise levels due to traffic and for air quality which was also 50% better than the current situation.

Given that zero responses to willingness to pay questions are a common feature, those who supplied such a response were asked the reason for their zero willingness to pay. The possible responses were:

- Not worth paying anymore/not bothered about improvements
- Noise levels/air quality cannot be improved in this way
- Not prepared to pay more council tax
- Other

Table 9 indicates the distribution of households' responses between the various categories. It can be seen that a minority of respondents expressed an actual willingness to pay, whilst the main reason for a zero willingness to pay is an aversion to paying more council tax.

Table 9: Nature of Households' Willingness to Pay Responses

	Noise	Air
Not worth paying/not bothered about improvements	72 (17.9%)	64 (15.9%)
Cannot improve noise/air quality in this way	27 (6.7%)	26 (6.5%)
Not prepared to pay more council tax	124 (30.8%)	113 (28.0%)
Other	33 (8.2%)	38 (9.4%)
Will Pay	147 (36.5%)	162 (40.2%)

81% of respondents had a positive value for both air and noise or a zero valuation of both attributes. Of those valuing only one attribute, there were slightly more providing air quality valuations.

The money valuations will clearly depend on whether those with zero willingness to pay are included or not. The large differences between the valuations based on all respondents and just those based on those with a positive willingness to pay can be seen in Table 10.

Table 10: Households' Willingness to Pay Valuations (£ per week)

	Obs	Mean	SD	SE	10%	25%	50%	75%	90%
Noise (All)	403	1.39	3.21	0.16	0.00	0.00	0.00	2.00	5.00
Noise (Non Zero)	147	3.82	4.36	0.36	1.00	1.00	2.50	5.00	7.00
Air (All)	403	1.49	3.29	0.16	0.00	0.00	0.00	2.00	5.00
Air (Non Zero)	162	3.72	4.32	0.34	1.00	1.00	2.00	5.00	10.00

Note: SD and SE denote the standard deviation and the standard error respectively, and the % terms denote percentiles.

The issue therefore becomes one of deciding the extent to which those with zero valuations are removed from the calculations. Our view is that those who stated that noise levels or air quality could not be improved through a process of raising council tax should be removed from the calculations since they have simply given a zero valuation because we have not offered an appropriate surrogate market for the valuation of the attributes in question. Those who are not bothered about improvements should be retained since their zero valuation is valid. The issue is less straightforward for those who would not be prepared to pay increased council tax, which is unfortunate given the size of this group. It is certainly the case that those with zero valuations would not be prepared to pay additional council tax even if it secured improvements in noise and air quality levels. However, there may be an element of protest here against council tax increases. We will retain these responses in our calculation of the average values, since the SP exercise contained the same monetary instrument, although we should bear in mind that this will lead to valuations which will tend to be lower than is really the case. Omitting just those who felt that noise levels and air quality could not be improved in this way results in weekly valuations and 95% confidence intervals based on the households' willingness to pay data of:

- Noise                    £1.49 (±22%)
- Air Quality            £1.60 (±21%)

The weekly valuations of a percentage improvement in noise and air quality levels are 2.98 pence and 3.20 pence respectively. The same questions were asked of businesses, except that the business rate was used as the monetary instrument rather than council tax. The business data set is much smaller and contains only 26 firms. Table 11 shows the different types of response to the willingness to pay questions. The noticeable difference compared to households is that a very large proportion of businesses have a zero valuation because they are not bothered about the improvements. This is not an unexpected finding.

Table 11: Nature of Business' Willingness to Pay Responses

	Noise	Air
Not worth paying/not bothered about improvements	16 (61.5%)	14 (53.8%)
Cannot improve noise/air quality in this way	0 (0.0%)	0 (0.0%)
Not prepared to pay more business rates	1 (3.8%)	1 (3.8%)
Other	1 (3.8%)	1 (3.8%)
Will Pay	8 (30.8%)	10 (38.5%)

Using the same reasoning as for the household sample, and given that there were no respondents who stated that noise and air quality could not be improved in this way, the weekly valuations and 95% confidence intervals based on the business willingness to pay data are therefore:

- Noise                    £12.81 (±92%)
- Air Quality            £12.80 (±91%)

The average weekly valuations of a percentage improvement in noise and air quality levels amongst businesses are both 25.6 pence.

Finally, we developed regression models in an attempt to explain variations in willingness to pay across households as a function of the household characteristics in our data set. The

results are presented in Table 12. This was done only for the household data since there were too few business valuations upon which to conduct analysis.

For both the noise and the air quality models, only three independent variables were found to have a statistically significant influence on the willingness to pay response. These were annual household income (INC), in thousands of pounds, the number of people in the household (NHH) and whether the current noise or air quality conditions were poor or very poor (POOR).

As expected, households are prepared to pay more for a proportionate improvement in noise or air quality when this is applied to current conditions which are poor or very poor. There is also a positive relationship between the willingness to pay and both income and household size. Whilst it is encouraging that each of the independent variables have the expected sign, it is disappointing that they can explain only a very small amount of the variation in willingness to pay data and that the responses apparently contain significant random error.

Table 12: Weekly Willingness to Pay Regression Models

	Noise	Air
Constant	-0.238 (0.60)	-0.237 (0.59)
INC (£,000's)	0.029 (2.73)	0.021 (1.96)
NHH	0.331 (2.39)	0.440 (3.09)
POOR	0.767 (2.26)	0.922 (2.54)
Adjusted R Squared	0.06	0.06
Observations	376	377

## 5 HOUSEHOLD STATED PREFERENCE RESULTS

The household surveys were conducted in Edinburgh between September and November 1996 after piloting of the approach. Interviews were completed in 403 households and this implies a maximum number of observations for modelling purposes of 6448. In the event, we modelled 3078 (48%) observations across 315 (78%) households. The reasons for omitting observations were as follows:

- i) 336 observations (5%) were omitted because the respondent had not supplied all the necessary details. In particular, journey times to zones to which trips were made were not provided.
- ii) There were many instances where an implausibly large amount of time was spent travelling. We suspect that a contributory factor here might be the presence of trips made in the course of work which are not of interest to us. This led to the removal of 1008 observations (16%).
- iii) We removed 1367 observations (21%) where the 100% improvement in noise levels was offered and 527 observations (8%) where the 100% improvement in air quality was offered. We had presented these levels to individuals as twice as good as the current situation and initial analysis of the data suggested that many were interpreting this as the same as the 50% improvement. Similar problems were not apparent for the twice as bad (100% worse) and 50% worse levels that were presented.

- iv) Finally, we lose 132 observations (2%) where the respondent had not expressed a preference between the two alternatives.

A novel feature of the study has been an attempt to link environmental valuations with actual environmental conditions. Air quality was measured in terms of NO<sub>2</sub> levels (in µg/m<sup>3</sup>). The levels recorded at each site used in the location specific presentation are given in Table 13. Unfortunately it was not possible to take measurements of air quality and noise levels at each household's residence. Of the 315 households upon whom the modelling is based, a noise measurement was available for 120 (38%) and an air quality measurement was available for 119 (38%).

Table 13: Site Used in Air Quality Presentation and NO<sub>2</sub> Levels (µg/m<sup>3</sup>)

Worst Sites	NO <sub>2</sub>	Best Sites	NO <sub>2</sub>
1 Gorgie Road	38	1 Clermiston Hill	18
2 Leith Walk	54	2 Carrick Knowes Golf Course	19
3 Clerk St	38	3 Arthur's Seat	11
4 Festival Square	34	4 Colinton Playing Fields	13
5 St John's Road	45	5 Braid Hill	24

We have linked the air quality levels presented to individuals with the air quality measurements where this was possible. Given that air quality measures are not available for all households, and that two different means of presentation have been used, the estimated model contains four different air quality variables.

**Air-PM:** This denotes that the percentage change method has been used and that air quality has actually been measured for this household and hence the percentage changes are applied to the measure of the current air quality so that absolute air quality measures are entered into the model.

**Air-PNM:** This denotes that the percentage change method has been used but that there is no measure of the household's current air quality available. In such cases, the variable is specified as a percentage change.

**Air-LM:** This denotes that the location method of presenting air quality has been used and that an air quality measure is available for the residence. Since the air quality has been measured at the two alternative locations, this variable can enter the model as an absolute air quality measurement.

**Air-LNM:** This variable denotes that the location method of presenting air quality has been used but that no air quality measure is available for the residence. Whilst we could compare the worst and best scenarios in terms of absolute air quality measures, the basic approach here is to specify dummy variables for three of the four differences presented.

Noise is specified as a proportionate change. For all the environmental quality variables, the following notation is used:

- 1 denotes a movement from a worse situation to the current situation
- 2 denotes a movement from the current situation to a better situation
- 3 denotes a movement from a worse than current situation to a better than current situation.

The model estimated to the 3078 observations is reported in Table 14. Time-C and Time-B are the accessibility and represent the amount of time the household spends travelling in a car and by bus. They are presented here because they are part of the estimated model. However, the focus of this paper is on the environmental variables and hence we only comment that the implied values of time seem to be too low and we have some concerns that respondents have not fully accounted for the preferences of all household members. For example, a respondent who is primarily a car driver may not have expressed an appropriate willingness to pay for time savings amongst other household members who use bus, and further analysis of this issue is required.

Table 14: Household Stated Preference Model  
(t statistics are given in brackets)

Variable	Coefficient (t)	Variable	Coefficient
Time-C (Save)	-0.0035 (3.9)	Air-PM2	-0.0380 (1.8)
Time-C (Loss)	-0.0049 (4.8)	Air-PM3	-0.0493 (3.9)
Time-B (Save)	-0.0002 (0.3)	Air-PNM1	-0.0152 (9.5)
Time-B (Loss)	-0.0017 (2.9)	Air-PNM2	-0.0196 (4.2)
Air-LM1	-0.0159 (1.3)	Air-PNM3	-0.0153 (3.6)
Air-LM2	0.0004 (0.1)	Noise1	-0.0125 (11.6)
Air-LM3	-0.0319 (3.9)	Noise2	-0.0068 (3.1)
Air-LNM1	-0.6147 (4.1)	Noise3	-0.0112 (8.3)
Air-LNM2	-0.6104 (3.5)	Tax1	-0.2154 (13.4)
Air-LNM3	-1.1480 (6.8)	Tax2	0.0139 (0.6)
Air-PM1	-0.0453 (5.2)	Rho Squared	0.180

Notes: Times are entered in minutes and costs are pounds per week.

The overall goodness of fit is quite satisfactory; it compares favourably with the levels typically achieved in more straightforward applications of SP choice exercises. Although many of the coefficient estimates have respectable t ratios, it should be noted that there has not been any allowance for repeated observations.

We have examined the sensitivity to council tax according to whether the tax variation is an increase beyond current levels (Tax1) or an increase up to current levels (Tax2). The response to an increase in council tax is statistically significant and has the required negative sign. On the other hand, respondents are not bothered about reductions in the council tax. Whilst there may be an element of protest in response to increases in the council tax beyond current levels, particularly given recent local government reorganisation in Edinburgh and sharp increases in council tax levels, such protests cannot account for increases to current levels having no effect on choices. Some alternative decision making process may be at work here, such as satisficing, whilst there may be an element of respondents not believing that council tax could be lower. In any event, the results show the importance of distinguishing between these two types of cost variation. We will examine below whether those who stated that they were not prepared to pay higher council taxes are more sensitive to cost variations.

As far as the valuations of air quality and noise are concerned, we can see that there is a tendency for the improvement from the current to some better position (2) to be less important than avoiding a deterioration from the current level to some worse level (1), the

exception to this being Air-PNM2. For the Air-LNM dummy variables, we cannot compare levels 1 and 2 but it is encouraging that the sum of Air-LNM1 and Air-LNM2 is reasonably similar to Air-LNM3.

Neither Air-LM1 nor Air-LM2 are statistically significant at the usual 5% level. This may be because of the small number of changes combined with relatively small changes in air quality. For Air-LM1, there are 237 cases and the mean change in NO<sub>2</sub> is 10.7 whilst the mean change for Air-LM2 is 13.3 across 240 observations. In contrast, Air-LM3 varies by 24.2 on average across its 236 observations. We have proceeded solely with Air-LM3 in subsequent models. The Air-PM coefficients are similar and there are no significant differences and thus subsequent models will contain only a single Air-PM term. The same applies to the results for Air-PNM.

The situation is a little different for noise. Noise2 is lower than the other two coefficients, significantly so with respect to Noise1. Whilst it could be argued that this is because improvements on the current situation are not valued, or else their benefits are not fully perceived, such reasoning would require Noise3 to be somewhat less than Noise1. Another possible explanation is that Noise1 and Noise3 contain the very large 100% increases whereas Noise2 contains only 50% improvements and the value of noise depends on the size of the change. However, when we included a dummy variable term to represent a 100% change to determine whether this was the likely explanation, its coefficient was insignificant. Subsequent models have combined Noise1 and Noise3 and maintained a separate Noise3 term.

Table 15 presents household monetary valuations based on the Tax 1 coefficient and with the various environmental quality variables above. The figures show that the valuation of environmental improvements are not trivial with improvements in air quality regarded as being more important than improvements in noise levels. Households would be prepared to pay 32 pence per week for a 10% improvement in noise levels according to the lower of the two noise coefficients in Table 15. Using the same proportionate scale for comparability, a 10% improvement in air quality would be worth 81.5 pence per week.

Table 15: Household Values for Air and Noise

Air-LM3	14.91p per unit NO <sub>2</sub>	Air-PM	21.14p per unit NO <sub>2</sub> (±28.3%)
Air-LNM1	283p (±47.8%)	Air-PNM	8.15p per % change (±17.86%)
Air-LNM2	287p (±51.3%)	Noise1&3	5.50p per % change (±15.9%)
Air-LNM3	530p (±26.7%)	Noise2	3.23p per % change (±61.1%)

Note: 95% confidence intervals expressed relative to the central estimate are in brackets.

However, our preference as far as valuing air quality is concerned is to use the location specific method since we believe that respondents are more able to relate to actual levels of air quality in different locations than to percentage changes in current levels. The valuation obtained using the location method of 15 pence per unit of NO<sub>2</sub> (Air-LM3) is somewhat lower than the value of 21 pence per unit of NO<sub>2</sub> (Air-PM) obtained using the proportionate change method. For those for whom an air quality measure was available, a 10% improvement in air quality would be worth 42 pence per week using the Air-LM3 valuation and this is around half the value obtained using the proportionate based valuation of Air-PNM.

## 5.1 Income Effects

We were also able to detect an income effect by segmenting the cost coefficient (Tax 1) by income group. Such a segmentation means that the monetary valuations of all the attributes will vary with income in the same fashion. The results of the income segmentation are presented in Table 16 as multipliers to be applied to a base valuation for the lowest income category. With the exception of the aberration for the highest income group, it is encouraging to be able to detect such a strong income effect.

Table 16: Income Group Multiplier

Income	Multiplier
<£10,000	Base
£10,000-£20,000	+23%
£20,000-£40,000	+44%
£40,000-£60,000	+126%
£60,000-£70,000	+189%
>£70,000	+12%

## 5.2 Segmentation by Initial Conditions

Where we have offered proportionate changes to current conditions in the SP exercise, which is the case for noise throughout and for air in about half the interviews, the valuations obtained should depend on the initial conditions since a given percentage change will yield a larger absolute change from worse conditions. Tables 17 and 18 present models which are segmented by the current conditions for noise and air quality respectively. For noise, separate models are presented for very noisy, noisy and fairly/quiete noisy conditions and the two noise valuations are reported. The remaining categories of quiet and very quiet contain too few observations to estimate meaningful coefficients. For air quality, we present the valuations relating to proportionate changes (Air-PM and Air-PNM) and also the Air-LM3 valuation.

Table 17: Noise Valuations Segmented by Current Conditions (pence per % change)

	Very Noisy	Noisy	Fairly & Quite Noisy
Noise2	8.27 (±51.7%)	6.93 (±66.4%)	4.33 (±64.5%)
Noise1&3	7.31 (±29.8%)	6.05 (±41.1%)	4.95 (±25.7%)
Observations	576	518	1604
Rho Squared	0.16	0.11	0.17

Note: 95% confidence intervals in brackets

We can see that a monotonic relationship is apparent for noise, with both valuations being positively associated with current noise levels. Given that those who have high valuations are more likely to live in quieter areas, it seems that any such effect is being outweighed by the larger absolute change effects. In addition, those who live in noisier areas might be more concerned to achieve given absolute improvements in noise levels.



Table 18: Air Quality Valuations Segmented by Current Conditions (pence per % change)

	Very Poor & Poor	Fair	Good & Very Good
Air-LM3	18.80 (±66.3%)	12.17 (±80.3%)	11.95 (±105.1%)
Air-PM	25.71 (±46.1%)	21.15 (±43.3%)	16.17 (±54.7%)
Air-PNM	9.00 (±39.7%)	5.23 (±48.2%)	7.51 (±21.8%)
Observations	893	995	1194
Rho Squared	0.17	0.14	0.15

Note: 95% confidence intervals in brackets

The results for air are less clearcut. The valuations based solely on the proportionate change in air quality (Air-PNM) do not exhibit a monotonic relationship with current conditions. The situation is not improved by introducing finer categorisations since there are few who reported very good or very poor air quality. On the other hand, the Air-PM valuation, which is based on absolute changes in air quality derived from proportionate changes applied to actual measures of NO<sub>2</sub>, does exhibit a strong relationship with current conditions. This is also the case for the Air-LM3 valuation. Again it may be that those who experience worse conditions are prepared to pay more for a given absolute improvement.

### 5.3 Segmentation by Nature of Willingness to Pay Responses

We here report valuations of noise and air quality estimated to the SP data which are segmented according to the following four categories of willingness to pay response:

- Not worth paying anymore/not bothered about improvements (WP1)
- Noise levels/air quality cannot be improved in this way (WP2)
- Not prepared to pay more council tax (WP3)
- Positive willingness to pay (WP4)

The results are given in Tables 19 and 20. It can be seen that those with a positive willingness to pay have somewhat larger valuations of noise. Indeed Noise2 is not significant for any of those who had a zero willingness to pay. However, Noise1&3 does not have the expected zero valuations in WP1, WP2 and WP3.

Table 19: Segmented Noise Valuations (pence per % change)

	WP1	WP2	WP3	WP4
Noise2	2.81 (±196.2%)	-3.61 (±144.6%)	2.54 (±126.5%)	6.11 (±52.61%)
Noise1&3	3.82 (±47.1%)	1.72 (±93.8%)	4.10 (±31.5%)	8.90 (±24.68%)
Observations	624	250	928	1033
Rho Squared	0.13	0.20	0.13	0.15

Note: 95% confidence intervals in brackets

With regard to the air quality valuations, we again observe larger valuations for those who had expressed a positive willingness to pay. However, those in WP2, who do not necessarily have zero valuations, have estimated valuations which are comparable with those who have a positive willingness to pay. It would seem that the SP exercise offers a more appropriate valuation context, on the grounds that it does not imply that council tax increases would be used to achieve environmental improvements, but merely obtains preferences amongst

different monetary outlays and environmental conditions. Although there are some large confidence intervals for the valuations in WP1 and WP3, it is again the case that many valuations are not zero.

Table 20: Segmented Air Quality Valuations (pence per % change)

	WP1	WP2	WP3	WP4
Air-LNM1	361.90 (±100.7%)	663.81 (± 49.2%)	57.92 (±352.9%)	592.50 (±42.3%)
Air-LNM2	795.24 (± 60.7%)	478.26(±101.7%)	73.33 (±320.9%)	504.00 (±45.9%)
Air-LNM3	619.05 (± 60.7%)	730.43 (± 71.5%)	270.83 (± 77.9%)	724.20 (±33.1%)
Air-LM3	9.81 (±145.7%)	-	13.33 (± 89.3%)	16.20 (±65.2%)
Air-PM	12.24 (±152.8%)	18.35 (± 97.5%)	7.04 (±178.3%)	40.40 (±28.6%)
Air-PNM	7.86 (± 38.5%)	6.09 (±108.1%)	4.58 (± 38.9%)	7.52 (±29.3%)
Observations	514	223	874	1199
Rho Squared	0.14	0.17	0.14	0.16

Note: 95% confidence intervals in brackets

Given the fact that the SP exercise obtained positive valuations when the willingness to pay values were zero raises the question of whether the willingness to pay responses are in fact biased, in order to reduce the chances of any council tax increase, or whether the SP exercise has in some way forced trading behaviour upon respondents. If an individual's valuation is truly zero, we find it hard to see why they should prefer increases in council tax in return for environmental improvements in the SP exercise, and on balance we feel that the SP responses are the more valid.

This is an appropriate place to compare the valuations obtained from the SP exercise and the willingness to pay questions. From the SP results, and for an improvement in environmental conditions, the valuation of a percentage change in noise is 3.23 pence (±61%). The willingness to pay valuation is 1.39 (±22%) for all respondents and 3.82 (±18%) for those with a positive valuation.

For air quality, we have adjusted the Air-PNM valuation relating to percentage changes according to the ratio of the valuations of Air-LM3 and Air-PM on the grounds that we feel that the location method of presenting air quality was more reliable. This yields a valuation of a percentage improvement in air quality of 5.75 (±18%). The corresponding willingness to pay values are 1.49 (±21%) for the whole sample and 3.72 (±18%) for those with positive values.

It comes as no surprise that the willingness to pay values are lower than the SP values since we suspect that the incentive to bias responses strategically is greater in willingness to pay exercises than in SP exercises. Given that we take the SP results to be preferred, it would seem that the willingness to pay valuations which omit zero valuations are more appropriate and hence we have some doubts about the validity of the zero willingness to pay responses.

## 6 BUSINESS STATED PREFERENCE RESULTS

The exploratory survey of small, independent businesses was conducted in February 1997 and 26 interviews were completed. This yielded 416 SP observations of which 25 were omitted because no preference was expressed between the two alternatives. The SP model

estimated to the data is reported in Table 21. Given the fairly limited sample size, there are some respectable t ratios whilst the goodness of fit is in line with that achieved in more conventional applications of SP choice exercises.

In the household exercise, we omitted scenarios where 100% improvements were specified due to concerns as to how respondents had interpreted twice as good. In the business model, we were more careful to specify what we meant by a 100% improvement in noise levels in that this meant that noise levels from outside would be zero.

Table 21: Business SP Model

Ped	0.0584 (0.2)	Noise3	-0.0087 (5.2)
Walk	-0.1971 (2.9)	Rates T1	-0.0792 (5.6)
Air1	1.2530 (4.2)	Rates T2	-0.0369 (2.4)
Air2	0.9933 (3.3)	Rates T3	-0.0189 (1.3)
Air3	0.8196 (2.9)	Rates Red	0.0323 (2.9)
Noise1	-0.0146 (4.5)	Observations	391
Noise2	-0.0015 (0.3)	Rho Squared	0.102

Pedestrianisation of the area around the office (Ped) was not regarded to convey any benefits to the business whereas the additional walking time implications had a statistically significant effect of the correct sign.

Air1, Air2 and Air3 are dummy variables representing the improvement from the worst location to the current location, the current location to the best location and the worst location to the best location. Noise1, Noise2 and Noise3 represent the impact of proportionate changes in noise levels for improvements up to the current situation, improvements from the current situation and improvements from a position worse than the current situation to a position better than the current situation.

There are three rates coefficients according to the firm's turnover. Rates T1, Rates T2 and Rates T3 represent the six, seven and thirteen firms respectively with turnovers of under £400,00 per annum, between £400,000 and £1 million per annum and over £1 million per annum. The final term listed is RatesRed which denotes an increase in business rates from a reduced level to the current level in contrast to an increase in rates beyond current levels.

The results with respect to the dummy variables for air quality are not as satisfactory as for the household SP model, since the sum of Air1 and Air2 far exceeds Air3. However, the results do suggest that air quality is an important issue. Unfortunately, we did not have air quality measures to allow analysis of other than by dummy variables.

The results for noise levels show a similarity with those for households in that improvements in current noise levels are not indicated as having any benefit and indeed Noise3 has a lower valuation than Noise1. However, it does seem that avoiding deteriorations in noise levels is regarded to be important.

Firms' valuations of accessibility and environmental quality may vary with a range of factors such as the number of staff, the number of trips made by employees, the number of customer trips to the office, the size of the office and the turnover. Given the limited sample size, we

have not pursued analysis of all these effects. Instead we have used turnover since it will capture a whole range of effects with which it is correlated. It can be seen that the sensitivity to a given cost variation diminishes as turnover increases; in other words, the valuations of environmental quality and accessibility will be greater as turnover increases.

We can see that again there is a greater sensitivity to increases in business rates beyond the current level than to increases up to the current level. In the model formulation that we have used here, only the companies in the smallest turnover category would be averse to increases business rates up to current levels.

As far as valuations are concerned, we will give some figures for increases in current rate levels for the two categories of firms which have significant cost coefficients.

Avoiding a 10% deterioration in noise levels would be valued at 184 pence and 369 pence per week respectively. Comparisons with the valuation of air quality is not straightforward since the proportionate change method of presenting air quality was not used. However, the willingness to pay to avoid air quality deteriorating to that associated with the worst location offered is equal to 1578 pence and 3395 pence per week respectively. These figures would seem to be quite appreciable.

## 7 CONCLUSIONS

Although further analysis of the data sets we have collected is warranted, and the analysis reported here has thrown up some issues which need to be resolved, we believe that this study provides an important contribution to the body of empirical evidence relating to the monetary valuation of transport related environmental factors. The results indicate that valuations of environmental factors by firms and households are not trivial. Nor did they seem to be implausibly large.

Changes in air quality are valued more highly than corresponding changes in noise levels and deteriorations in environmental quality had greater valuations than improvements. There was also greater resistance to increases in council tax beyond current levels than to increases up to current levels. Further research is required to establish the cause of these findings.

The study provided results relating to both accessibility and environmental factors which have been used to enhance a strategic transport and land use interaction model (Bristow et al 1998).

An important feature of the research was an attempt to relate the values to current conditions and noise and air quality measures were obtained for some households. The air quality measures have been used in the modelling of preferences towards air quality. However, further research is needed to do the same for noise levels.

Another element of the research was a comparison of two means of presenting air quality according to proportionate changes or else by reference to different levels of air quality in different locations with which the respondent would be familiar. Our preference is for the latter approach, which yields lower and we would argue more plausible values. Although we

did not pursue this approach in presenting different noise levels, we would recommend that further research should consider means by which this might be progressed.

The values obtained from the households' willingness to pay questions were lower than those derived from the stated preference analysis. We believe that the incentive to bias responses is greater in the willingness to pay questions.

There was quite strong evidence to suggest that the valuations of noise and air quality are dependent upon existing environmental conditions. The valuations were higher where conditions were worse and in further research this could be built into an appropriate functional form of the model.

Finally, our results are based on hypothetical questioning, yet we recognise that it might well be possible to develop models based on actual residential and location choices. We would recommend that such an approach be considered for further research in this area. This might well contribute to further improved understanding of the link between environmental valuation and location choice models.

#### ACKNOWLEDGEMENT

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"E3" Valuation of Internal and External Benefits/Costs

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**External Costs of Road, Rail and Air Transport - a Bottom-Up Approach**

(revised version)

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## 1 INTRODUCTION

This paper describes the most important results of the external quality valuation in the QUITs project\* funded by the European Commission (DG VII) under the Transport RTD Programme of the 4th Framework Programme. The objective of QUITs was to develop a methodology for valuing internal and external quality dimensions of transport systems.

A uniform methodology is applied for calculating external costs of transport for different types of impacts and transport modes. The evaluation of the external costs of road, rail and air traffic for both passenger and goods transport is based on a bottom-up approach, which means that the starting point for the analysis is the micro-level. This is standard in cost-benefit analysis. We adopted the impact pathway approach developed in the ExternE project (IER *et al.*, 1997). Due to limited space, this paper will focus on the comparison of external costs between modal alternatives for the route Frankfurt - Milan. This Origin-Destination relation is transnational, covers all major kinds of transport-related externalities and offers a real modal choice. The bottom-up approach can be applied both, to support a netwide analysis and for local and route specific cost-benefit analysis. Monetary valuation is essential to get an orientation towards fair and efficient pricing.

## 2 GENERAL FRAMEWORK FOR THE VALUATION OF TRANSPORT EXTERNALITIES

### 2.1 External costs of transport

Externalities are changes of welfare which are caused by economic activities without being reflected in market prices (Rothengatter, 1993). With regard to the transport sector, relevant external costs are negative externalities which occur when transport consumers/producers impose higher costs on society than they bear themselves. In the enclosure of this paper, the external costs of transport include:

- air pollution,
- climate change,
- traffic noise, and
- accidents (as far as they are not internalised through insurance premiums).

Due to a lack of micro-data, infrastructure costs (as far as they are not covered by charges) and subsidies were not analysed in detail and will not be presented here.

An ongoing debate revolves around the question whether *external benefits* have to be considered in valuation studies. Some studies tried to identify specific external benefits of transport, like regional development effects or productivity benefits (Aberle, 1995). However, a critical review of these studies shows that nearly all benefits of transport services have to be paid by the users, i.e. the benefits are *internal* and included in market prices, respectively.

Congestion, as a non-environmental effect, induces external costs between individuals, but not between the transport system and other systems. Hence, from the perspective of the QUITs project, congestion is part of the internal quality of the transport system, which is not included in this paper.

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\* QUITs: Quality Indicators for Transport Systems carried out by ISIS, ENEA, INISTENE, ZEW, ISI-Fraunhofer, WHO-ECEH

Table 1 gives a survey of the different categories of external costs of transport activities, as described in a report of the project Pricing European Transport Systems (PETS, 1997).

Table 1: Transport externalities

		Internal Costs		External Costs	
		to individuals	to the sector		
Social Costs	Environ- mental Costs	fauna & flora	own disbenefits (individual)	own disbenefits (sector)	uncovered environmental costs
		energy			
		noise			
		air, water, land			
		landscape eff. vibrations			
Costs	Congestion Costs	time lost by the user (and the increase of other direct costs)	time lost by other users (and the increase of other direct costs)	costs provoked on others outside the transport sector	
		Accidents	own accident costs and costs covered by insurances	costs covered by insurances	uncovered accident costs
		Infrastructure Costs	tolls, vehicle and fuel taxes	unperfected allocation of costs	uncovered infrastruct. costs
		Transport Expenditure	fuel/vehicle costs or tickets and fares	unperfected allocation of costs	costs covered by others

Sources: adapted from Button, 1993a and CEMT, 1996; cited in PETS (1997)

## 2.2 Valuation of health risks due to air pollutants and accidents

The valuation of mortality is often criticized from an ethical standpoint for putting monetary values on human lives. From an ethical point of view, it is argued that monetary valuation "neglects to account for the popularly perceived 'right' not to be subjected to physical harm by other people" (Goodstein, 1994) and that people would value a certain human life infinitely high. However, such a standpoint cannot explain the real behaviour of people, because it would imply that legislation can prevent all external health effects and that people are willing to pay infinitely high amounts of money for risk reduction.

In reality, people weigh the costs and benefits of investments in seat belts, air bags, or earthquake protection carefully. This economic behaviour of people is the object of research in studies valuing risks to life and health. Values of mortality and morbidity risks are derived from individual preferences revealed by people's market behaviour or by contingent valuation surveys.

Thus, the value of statistical life (VSL) is used in economic studies as a measure of welfare losses caused by risks to life. Mathematically, the average willingness to pay (WTP) for reduced mortality risks is divided by the risk reduction being valued. For instance, the VSL is 1 million dollars if the average WTP for a risk reduction of 1 in 10,000 is \$ 100. It is important to mention that the VSL is not a measure of the life of a known individual or the death of a specific individual. Rather it refers to the statistical risks before the damage occurs, i.e. it is not known which individuals will actually be damaged, but it can be ascertained to what extent damages are to be expected. The economic value of a health risk

is the amount an individual is willing to pay to avoid a risk, or the amount for which the individual would be willing to accept the risks (Ewers *et al.*, 1994).

In the ExternE study commissioned by the European Commission, a meta-analysis of contingent valuation and hedonic pricing studies was made. Thus, a VSL of 2.6 million ECU was recommended (Markandya, 1993). For the base year 1995, this value was updated to 3.1 million ECU (i.e. 2.6 million ECU in 1990-prices adjusted with the consumer price index to 1995-prices, IER *et al.*, 1997). The VSL is a rough, average value for an average risk reduction and does not distinguish between determinants like the age at exposure, latency or future quality of life, which are important factors for the individual WTP. In the ongoing ExternE project (phase III) it was decided to introduce values of a life year lost (VLYL). The approach is based on the assumption that the VLYL is independent of people's age and life expectancy. There is little empirical evidence for this assumption in the literature, especially for acute mortality (IER *et al.*, 1997). Concerning the limited empirical evidence of each approach with regard to acute mortality, values for both VSL and VLYL (and years of life lost (YOLL), respectively) were calculated in QUITTS. For chronic mortality, only YOLL values will be quantified due to a lack of VSL impact data. Due to limited space, for health effects caused by air pollutants only values calculated on the basis of the YOLL concept will be presented here.

In analogy to mortality risks, morbidity risks can be estimated by using contingent valuation and hedonic pricing studies or by calculating production losses. The latter is referred to as costs of illness (COI). COI values calculate medical treatment plus lost earnings. A survey of the methods and their empirical evidence is given in Rennings (1995).

For the QUITTS project the following values were used (1995 prices in ECU):

- mortality with a VSL of 3.1 million ECU,
- non-fatal accidents with the values from a recent study commissioned by the British Transport Research Laboratory (TRL) (in 1995 ECU values: 134,320 ECU for a serious, 13,210 ECU for a minor accident) and
- other morbidity effects with ExternE values (see Chapter 3.2).

As was shown by Rennings (1995), these social costs are only partially internalised through compensations paid by health insurance companies and employers' liability insurance associations. Such compensations are mainly based on the costs of illness. For morbidity, COI covers around 30 per cent of the induced social costs. Compensation for mortality risks exists in the form of rents for surviving dependants. However, even an average rent of ECU 10,000 per year paid for a period of 25 years covers less than 10 per cent of VSL. Thus, it can be concluded that around 30 per cent of non-fatal and not more than 10 per cent of fatal health effects are internalised through payments made by health insurance companies and employers' liability insurance associations.

Although external costs of health risks depend on income and different values can be calculated for different European countries (Kageson 1993), in QUITTS we preferred using an average value for the European Union.

### 2.3 Valuation of global warming

In several contributions, damage cost calculations of climate change like those of Nordhaus (1991) and Cline (1991) were criticised from an ecological perspective in particular. It was argued that mere neoclassical optimisation concepts tend to ignore the ecological, ethical and social dimensions of the greenhouse effect, especially issues relating to an equitable distribution and a sustainable use of non-substitutable, essential functions of ecosystems. Most of the critical arguments pointing out the limits of traditional cost-benefit-analysis can be found in the IPCC Second Assessment Report (IPCC 1995).

Responding to the IPCC's criticism, Fankhauser *et al* (1995) and Tol (1996b) derived a research agenda for the economic assessment of climate change impacts including:

- improved damage estimates for less developed countries;
- improved estimates of non-market losses, especially of morbidity and effects on the ecosystem;
- assessment of the importance of variability and extreme events;
- models of the process of adaptation and the dynamics of vulnerability;
- formal uncertainty assessments and analyses of the outcomes;
- improved comparisons and aggregations of estimates between countries;
- improved comparisons and aggregations of estimates between generations;
- ensuring consistency between economic and non-economic impact assessments.

With regard to this research agenda, first advances are observable, especially concerning the handling of intra- and intertemporal equity questions. Additionally, some efforts have been made towards a more dynamic modelling of climate change damages, which will not be discussed in this paper (for details see Tol 1996a).

Concerning intergenerational equity, the concept of time-variant discounting was introduced (Azar *et al*, 1996, Rabl, 1994) and then applied in QUITTS. Thus, the following range of discount rates was used:

- 0 per cent as a rate for long-term effects which can be expected to rise with income (> 30 - 40 years),
- 1 per cent as rate for social time preference (STP) ignoring individual time preference (ITP) (other long-term effects),
- 3 per cent as a rate for STP including ITP (standard discount rate for short-term effects, < 30 - 40 years) and,
- 6 per cent as a rate for the opportunity costs of capital representing market interest rates.

The concept of time-variant discount rates seems to be consistent with the principles of welfare theory. While 3 per cent can be used as a standard discount rate, lower rates can be applied for long-term global warming effects.

Intragenerational equity questions were addressed in contributions by Fankhauser *et al* (1995) and Azar *et al* (1996). Both use an equity weighting approach: on the basis of the existing estimates of global warming damages, willingness to pay values are adjusted in the aggregation process. While aggregating estimates for single countries or world regions to a global value, the damages are weighted by the inverse of income. Damages of rich countries are weighted down and damages of poor countries are weighted up by adjusting

these damages to the average annual per capita world income. The reason for the adjustment is the „decreasing marginal utility of money and for the same reason we can argue that a given (say one dollar) cost which affects a poor person (in a poor country) should be valued as a higher welfare cost than an equivalent cost affecting an average OECD citizen“ (Azar *et al* 1996). Thus, equity weighting leads to the result that damages and deaths in developed countries do not count more than in developing countries.

It is obvious that equity weighting and the discount rate chosen will have a substantial influence on the level of investments for stabilizing the global temperature that can be justified by mere economic reasons. In the IPCC report with a range of \$ 5 -125 marginal costs per tonne of carbon, the lower bound of the range is derived from the Nordhaus study. Using mainly Nordhaus parameters and a model that takes the retention of carbon in the atmosphere into account, Azar and Sterner introduce time-variant discount rates and equity weighting as described above. In doing so, they calculate marginal damages in the range of \$ 260 - 590 per tonne. This is roughly 50 to 100 times higher than the Nordhaus value.

In QUTS, we used the results of the global warming sub-task of the ExternE Phase III, which took both inter- and intragenerational equity into consideration (Table 2). For other greenhouse gases, CO<sub>2</sub> equivalents will be used according to Schimmel *et al* (1996) and Hauschild *et al* (1996). The CO<sub>2</sub>-equivalents are e.g. 21 for methane, and 2 for CO.

Table 2: Recommended global warming damage estimates for use in the ExternE study

	Low	High
ECU (1995)/tC		
Conservative 95 % confidence interval	14	510
Illustrative restricted range	66	170
ECU (1995)/tCO <sub>2</sub>		
Conservative 95 % confidence interval	3.8	139
Illustrative restricted range	18	46

Source: Eyre *et al* (1997)

#### 2.4 Valuation of noise nuisance

Nearly all valuation studies on noise nuisance deal with the transport sector. Either the hedonic pricing method or the contingent valuation method are appropriate techniques for valuing welfare losses caused by noise nuisance (Pommerehne *et al*, 1992). The most common method in this field is the hedonic pricing approach. Only a few contingent valuation studies are available. Some other studies (e.g. Planco, 1990) calculate avoidance costs which are only adequate for estimating a lower bound of noise damage (Wittenbrink, 1992).

Noise emissions of transport activities affect humans mainly in two ways:

- negative physiological effects, e.g. change in heart rate, and blood pressure. 2% increase in heart attack risk (Ising *et al*, 1992).
- negative psychological effects, e.g. annoyance, disturbance of communication and recreation, insomnia, loss of (mental) productivity.

Due to the fact that over 60% of the noise nuisance is determined by psycho-social factors, and not directly by the physical burden measured in Leq, the CVM seems to be the appropriate monetisation method. Furthermore, our valuation relates to 5 dB(A)-classes

instead of 1 dB(A)-steps, because a change in the latter cannot be perceived and therefore not reported by the persons affected. This subjective perception of noise makes it difficult to measure marginal impacts. Another reason for the fact that even for very low traffic density the marginal costs of transport noise are very close to zero, is the rule in physics according to which the addition of sound sources is described by a logarithmic function.

Table 3: Noise costs per person exposed

Leq in dB (A)	50-55	55-60	60-65	65-70	70-75	>75
Road: ECU/a	15.46*	61.85	247.41	618.52	1237.04	2474.08*
Rail: ECU/a	3.87**	15.46*	61.85	247.41	618.52	1237.04

\* additionally given by IWW/INFRAS (1995); \*\* own estimation

Source: Hansson (1985) cited in IWW/INFRAS (1995). The original Hansson values are given in 1991 Swedish kronor.

Our approach is founded on the Swedish valuation study by Hansson (1985) cited in IWW/INFRAS (1995). There are two reasons for this choice. First, the figures calculated by Hansson represent a (European) mean of current assessments. Second, values for noise nuisance classes >60 dB(A) are included, too (IWW/INFRAS 1995). The applied "railway bonus" of 5 dB(A), which is prescribed in the German noise protection ordinance 16. BImSchV (BMV 1990), becomes evident in a shift of valuation classes to the right (see Table 3). The reason for the bonus is that at the same emission levels Leq. noise from trains annoys people less than noise produced by road traffic

From the bottom-up analysis we derive separate emission values for day and night, as prescribed in the above mentioned ordinance. Hence it is necessary to make a distinction in the valuation process. We therefore consider the WTP functions for silence evaluated by Weinberger *et al* (1991). The specific values for one hour of silence are about 10 % higher for the night than for the day.

To get specific values (ECU/pkm and ECU/tkm), we follow the Planco study (1991). For road traffic, the external costs for day and night are divided between passenger and goods traffic according to a 1:10 ratio. For rail traffic, the differences between passenger and freight traffic have already been taken into consideration in the formulas for the bottom-up emission calculation. In general a freight train is about three to four times louder than a passenger train (IWW/INFRAS 1995).

### 3 METHODOLOGICAL FRAMEWORK FOR MEASURING ENVIRONMENTAL AND HEALTH IMPACTS OF TRANSPORT SYSTEMS

#### 3.1 Overall approach

The method which will be used to evaluate external costs is a "bottom-up" approach for the route Frankfurt - Milan. This means that the starting point for the analysis is the micro-level. The bottom-up approach applies detailed models of emissions and impacts and offers several advantages compared to top-down approaches, which are widely used in damage assessment. Different fuels, technologies and sites with different traffic situations (speed, congestion, slope, etc.) can be addressed. This makes it possible to develop a more comprehensive, consistent accounting framework for estimating external costs of transport activities. QUITTS focused on the analysis of the external costs caused by the current traffic situation on the route, thus, main results are calculated for a given technology mix.

Besides, for road and rail traffic specific values are calculated for the main technologies (petrol cars with and without catalytic converters, diesel cars, highspeed trains).

The calculation of the external costs involves four stages: emissions (burdens), dispersion (concentrations), quantification of impacts, and external costs. These steps are derived from the damage-function approach developed in the ExternE project (European Commission, 1994).

It has to be mentioned that in the external valuation methodology the emphasis is on the use of infrastructure for transport activities. The impacts of fuel production (in the case of road and air traffic), vehicle production, maintenance and disposal and the supply of infrastructure are not taken into account. This is in contrast to the ExternE methodology which takes impacts from all stages of the fuel cycle into consideration.

The methodological approach of the QUITTS externality analysis is summarised in Table 4, and will be used in this paper, too. The first column lists the transport modes considered (passenger and freight transport for road and rail traffic as well as passenger air traffic) and the accompanying transport technologies. The next four columns include the four stages of the damage pathway:

Table 4: QUITTS methodological approach of the externality analysis

Traffic modes (technologies)	Burdens (emissions)	Dispersion modelling, concentrations	Quantification of impacts	Valuation of impacts (burdens)
<b>Road traffic</b> a) passengers - "car" - mix: petrol with and without cat, diesel b) goods - mix of vans, light and heavy trucks	<u>Air pollutants:</u> - CO <sub>2</sub> - CH <sub>4</sub> (CO <sub>2</sub> -equivalent) - CO (CO <sub>2</sub> -equivalent) - SO <sub>2</sub> - NO <sub>x</sub> - Particulates (PM <sub>10</sub> ,...) - Benzol - HC - non-methane HC - Pb - other micro-pollutants	<u>Emission source: linear Integrated model:</u> • 0 - 200 m: In-function from MLuS-model • 200 - 5,000 m: empirical exp.-function • >5,000 m: EcoSense <u>Results:</u> Concentration changes: SO <sub>2</sub> , NO <sub>x</sub> , PM, nitrates, sulphates, acid deposit.	<u>Human health:</u> - Mortality - Morbidity <u>Environmental:</u> - Materials: <i>maintenance facades of buildings</i> - Crops: <i>Yield losses</i> - Forests: <i>timber losses</i>	<u>Direct valuation methods:</u> - Contingent valuat. method (CVM) - Market simulation <u>Indirect valuation methods:</u> - Hedonic price analysis (HPA) - Wage risk analysis (WRA) - Travel cost approach - Production losses - Avoidance costs - Costs of illness (COI)
<b>Rail traffic</b> a) passengers - conventional - high-speed b) goods - only electric. powered trains	<u>Other pollutants:</u> - soil - water <u>Accidents</u> <u>Noise</u> <u>Others</u>	<u>Emission source: point Model used:</u> • EcoSense <u>Results:</u> Concentration changes: SO <sub>2</sub> , NO <sub>x</sub> , PM, nitrates, sulphates, acid deposit.	<u>Climate:</u> - Global warming	
<b>Air traffic</b> a) passengers -diff. airplanes	- vibration - cutting-off-effects - visual intrusion	<u>Emission source: linear</u> • rough calculation with EcoSense	<u>Non-environm:</u> - infrastructure - subsidies	

Source: Weinreich *et al* (1998)

The analysis starts with the exposure (number and kind of kilometres driven). **Burdens (mainly emissions)** in the form of air, soil and water pollutants, noise, or vibrations and possibly also accidents occur. The burdens can be quantified for one trip or for one year, i.e. the reference year 1995. For the calculation of airborne road traffic emissions a specific model (Workbook on Emission Factors for Road Transport, short: hb-efa; Infrac, 1995) is used allowing a very complex analysis of road traffic emissions on particular routes, both for passenger and freight transport. The programme requires users to choose from the following parameters:

- emission type(s): "hot" emission factors, cold-start boosts, evaporation emissions (after the engine has been switched off and/or as a result of tank breathing); only available for cars, for trucks only hot emission factors
- vehicle category(ies): cars, vans, trucks, busses, motorbikes
- reference year and – related to the reference year – a typical mix of vehicle types within each vehicle category (e.g. cars = weighted mix of conventional petrol cars, different types of catalytic converters, conventional diesel cars, diesel US- and EURO-norm; trucks = mix of different diesel technologies depending on age)
- kind of pollutants: CO, HC, NO<sub>x</sub>, PM (particles), CO<sub>2</sub>, Pb, SO<sub>2</sub>, CH<sub>4</sub>, non-methane HC, benzol
- traffic situation: type of road (e.g. motorway, different kinds of urban roads), speed, traffic flow (number of vehicles/hour, stop-and-go traffic, congestions)
- slope (0 %, 2 %, 4 %, 6 %)

Depending on the parameters chosen, the programme calculates the resulting emission factors (in g/vehicle-km) for each vehicle category (assuming a typical mix of vehicle types of the reference year) or for each vehicle type. Road emissions are calculated by taking into account the country-specific vehicle mix on each part of the route (see Table 5).

Table 5: Country-specific vehicle mix (cars and trucks), share in %

cars	D	CH	I	trucks	D	CH	I
	petrol with cat.	66.2	73.3		16.1	70's and 80's	72.7
petrol (no cat.)	12.7	19.9	68.4	EURO1	22.7	16.0	25.0*
diesel	21.0	6.8	11.3	EURO2	4.6	0.0	
other	0.0	0.0	4.3				

\*) On the assumption, that all 90's trucks correspond to the EURO1 norm

Sources: Infrac, 1995 (D, CH); A.C.I. (1996); estimates made by ISI

For the other transport modes, emissions are calculated for the different technologies (airplane types, train engines), taking into account the route-related vehicle flows and occupancy (load) factors, the specific energy consumption, and the accompanying emission factors. For rail traffic, the country-specific emission factors of electricity generation (fuel mix of the railway electricity generation) are used.

Besides the calculation of air pollutants, the first stage of the damage pathway approach includes the counting of accidents (see Chapter 3.5) and the calculation of noise emissions from rail and road traffic (see Chapter 3.4).

In the second stage, burdens are translated into concentrations. The results of this stage are emission levels (concentrations) relating to the modes of transport. In the case of road transport, the dispersion of airborne emissions is calculated with an integrated model which is explained in the next chapter. The dispersion of noise is quantified taking into consideration the population concerned along the road/rail track. For accidents, this stage of the analysis is not relevant.

The third stage is the quantification of impacts, which are divided into human health, environmental, climate, and non-environmental effects. These impacts have to be identified and – if possible – quantified by exposure-response functions. The impacts on human



health (mortality and morbidity) can be caused by both accidents and pollutants. The environmental and climate impacts are caused by emissions or concentrations.

The fourth stage includes the valuation of the impacts, or in some cases directly of the burdens. The valuation methods listed in the column are based on willingness to pay analyses. The results of this evaluation process are expressed in monetary units, i.e. external costs.

A question which has to be answered for the concrete realization of the impact pathway methodology is which impacts should be included and next which emissions should be taken into account in the assessment of the impacts chosen. Methane (CH<sub>4</sub>), carbon monoxide (CO), and carbon dioxide (CO<sub>2</sub>) are known to contribute to the greenhouse effect. Therefore, they are included in the analysis of climate change costs according to their global warming potential.

Sulphur dioxide (SO<sub>2</sub>), oxides of nitrogen (NO<sub>x</sub>), carbon monoxide (CO), and particulate matters (PM) are responsible for impacts on human health, crops, forests, and materials, both directly and as secondary pollutants formed in the atmosphere. A weakness of this analysis is that the assessment of transport requires a distinction between different size fractions of particulate matter, PM<sub>10</sub> and PM<sub>2.5</sub>, which is not made in the model. This differentiation would be important due to the very fine nature of transport particulate emissions.

Ozone, as a major photochemical oxidant, results from atmospheric chemical reactions between hydrocarbons and oxides of nitrogen in the presence of sunlight. At present, no regional model of ozone formation and transport is applicable to the European situation. There are some simplified approaches to the assessment of ozone effects (Rabl and Eyre 1997 and Hurley and Donan 1997, cited in IER et al 1997). They provide damage factors of 1,500 ECU/t NO<sub>2</sub>, 930 ECU/t NMVOC, and 130 ECU/t CH<sub>4</sub>. However, these results are not included in our analysis.

Other air pollutants which are quantified in the emission model are not included in the further calculation of external costs due to limited availability of reliable exposure-response functions. Some substances have been identified as potential initiators of cancer. But, "carcinogens, which were expected to play an important role due to their high specific toxicity, proved to be of much lower importance compared to the particles" (IER et al 1997).

### **3.2 An integrated model for the external cost analysis of interurban road traffic**

An integrated model will be presented for the calculation of road emissions, the dispersion of these emissions, the quantification of impacts by applying exposure-response functions and the valuation of the impacts. The use of the integrated model is limited to roads along which there are no or only a few buildings. This applies to nearly all segments of the route Frankfurt - Milan, as this interurban connection consists of a motorway running through the three countries concerned. It has to be mentioned that the results should not be transferred to the analysis of urban transport systems without making major modifications to the model. At least the dispersion in street canyons has to be included.

The integrated model consists of three models linked together. The model "Workbook on Emission Factors for Road Transport" analyses the emissions on roads/motorways as

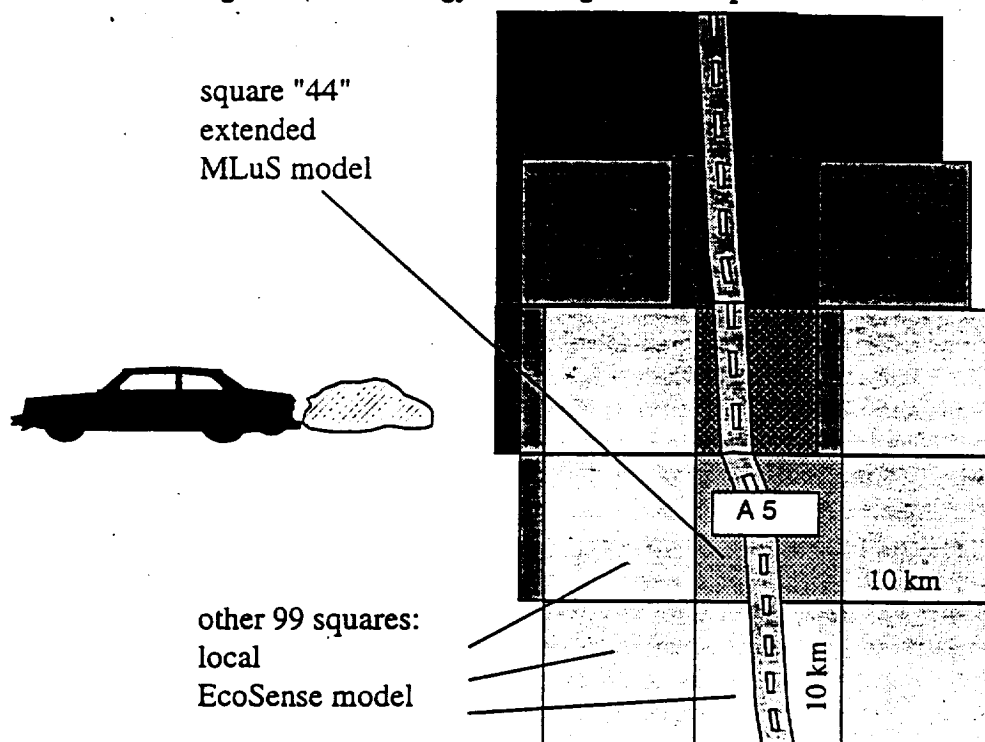
shown in the previous chapter. The bottom-up calculated emissions are the basis for the two dispersion models "MLuS" and "Ecosense" to calculate the external costs of interurban road transport. While MLuS only aims to analyse the concentration change due to emissions from road traffic on a very local scale (up to 200 metres around the road), Ecosense covers the dispersion of emissions over much greater distances up to several thousand kilometres.

Ecosense was developed as an integrated computer system for the assessment of environmental impacts and external costs resulting from electricity generation systems (IER 1997). Based on the impact pathway approach, the model provides relevant environmental and population data and two air transport models (local: up to 100 km distance, regional: focus on the chemical formation of secondary pollutants) required for an integrated impact assessment of airborne pollutants. MLuS is a static regression model based on concentration measurements which were made at different distances of up to 200 metres from the edge of the road along three German motorways (Forschungsgesellschaft für Straßen- und Verkehrswesen, 1996). In order to link the two dispersion models it is necessary to extend the MLuS scale to a range of 0 to 5,000 m. The dispersion function of the air pollutants included in the MLuS model is used and extrapolated to 5,000 m.

The two dispersion models are linked to form an integrated model by relating the concentrations and impacts to geographical sectors. The whole route Frankfurt - Milan is divided into route segments each about 10 km in length. A 10x10 km square is related to each route segment the road runs through. For each square around the road the dispersion of the emissions is calculated using the extended MLuS model. The 10x10 km square is placed in such a manner that on each side of the motorway there is an area about 5 km wide. We apply the extended MLuS model for calculating the concentration change up to 5 km on both sides of the motorway. The valuation of the external costs of road traffic relating to the inner 10x10 km square has to be made step by step following the impact pathway. Therefore, the recipients of the impacts have to be identified and located, and the exposure-response-functions used in the EcoSense model have to be applied for the quantification of the impacts. In the last step, we will value the impacts in a way that is similar to the valuation method in the EcoSense model applied.

The local EcoSense model yields results for a grid of 100x100 km made up of 100 squares 10x10 km in size. The point source of air pollutants (normally the power plant) is located at the centre of square "44" which lies in the middle of the whole grid. As road traffic is a linear source of emissions, we calculate the dispersion within square "44" by using MLuS as explained above. The assumption is made that any concentration beyond the inner 10x10 km square is analysed as a point source emission. Thus, we apply the local EcoSense model beyond this inner square for the calculation of the concentration change due to air pollutants emitted while driving through square "44". The values relating to the concentration change in the inner square must be subtracted from the result of the local EcoSense model run to avoid counting square "44" double. The whole procedure is repeated for each route segment. The methodology of linking the two dispersion models is illustrated in Figure 1. EcoSense calculates a concentration change value for a representative point in each square. To be consistent, also for square "44" one representative value is calculated by using the results from MLuS. It has to be mentioned that concentration changes in the direct neighbourhood of square "44" calculated by the local EcoSense model lie within the range of the figures of the extended MLuS model at a distance of 5,000 m.

Figure 1: Methodology of linking the two dispersion models



In a next step the route segments of each country involved in the route are aggregated to national route sections. The amount of emissions produced by driving through these route sections is the input data for the regional EcoSense model to calculate the dispersion, environmental and health impacts as well as the resulting external costs. Technically, the emissions are directly fed into the database system of the regional EcoSense model, which is divided into 100 x 100 km squares for the whole of Europe. Existing background concentrations have to be taken into account.

At present, we assume for all sites (all countries) on our route the same meteorological data as an input for the local EcoSense model (in the regional model the climate data is included), because the collection of this hourly data is extremely difficult. The data for population, buildings, agricultural areas and forests around the motorway are calculated by using district data in Germany, canton data in Switzerland, and regional data in Italy.

For the quantification of health impacts E-R functions are applied for acute mortality, respiratory hospital admissions, cerebrovascular hospital admissions, cardiovascular hospital admissions, emergency room visits (ERVs), restricted activity days, acute effects in asthmatics, respiratory symptoms in the general population, chronic mortality, and chronic morbidity.<sup>†</sup> Crops, forests and material are chosen as priority environmental impacts. In selecting the E-R functions we followed the recommendation of the ExternE

<sup>†</sup> Exposure-response functions are linear functions between concentration changes and human health impacts. The exposure response slope is for Western Europe and has units of cases/(yr-person- $\mu\text{g}/\text{m}^3$ ), except for mortality which is expressed as percentage increase per  $\mu\text{g}/\text{m}^3$ . Monetary values for the main health impacts are (in ECU 1995): acute mortality: 116250, chronic mortality: 84330, respiratory hospital admissions, cerebrovascular hospital admissions, cardiovascular hospital admissions: 7870, ERVs: 223, restricted activity days: 75, cough and wheeze in asthmatics: 7.5, bronchodilator usage: 37, and chronic bronchitis: 105000.

project group (IER *et al*, 1997). The applied E-R functions are all included in the current EcoSense model 2.0 and listed in the final report of QUITTS (Weinreich *et al* 1998). A comprehensive overview of the applicability and reliability of E-R functions is given in the reports of the ExternE project (European Commission 1994) and, especially for transport purposes, in the report by IER *et al* (1997). The latter gives a survey of the epidemiological literature with the resulting E-R functions and includes levels of uncertainty.

### 3.3 Dispersion and impact modelling for rail and air traffic

As far as possible the same burden categories, impact groups and ER-functions are used in the calculations for each transport mode. Concerning air traffic, no appropriate dispersion model is available which includes the specific conditions for emitting air pollutants high up (above 1,000 m). Thus, neglecting the emitting character of line-sources, we assume that all the air pollutants are emitted at the two airports: half in Frankfurt and half in Milan. This crude approach allows us to use EcoSense for the dispersion, impact assessment and calculation of external costs as a rough estimate of the effects of air traffic air pollutants. Local impacts of starting air planes are neglected in the QUITTS project for air pollutants and noise (see next chapter) due to limited resources. Thus, only the regional EcoSense model is applied. The environmental and health effects may be overestimated (not all air pollutants come down to the ground), but it can be argued too that the high global warming potential of high-level emissions leads to an underestimation of these impacts (Schumann, 1996).

Electrified rail traffic only produces air emissions from power plants as a point source. The dispersion of emissions from rail traffic is treated like in the energy sector. The regional EcoSense model is applied with an assumed location for the emission source, due to very limited information about the locations of the railway electricity plants. We argue that since obviously the power to run a locomotive on a South German route will not come from North Germany, an artificial point in the middle of the national route section is assumed. Thus again, the calculation of local impacts does not seem to be appropriate. Applying the regional impact quantification to airborne emissions from all transport modes ensures the comparability of the results.

### 3.4 Noise

Noise is unwanted sound or sounds of a duration, intensity, or other quality that causes physiological or psychological harm to humans (Marvin, 1993). Because of the complexity of noise, objective burdens are difficult to evaluate. The perception of sound as noise differs from person to person, from moment to moment. Only about 40% of the noise nuisance reaction can be described directly by means of the equivalent sound level ( $L_{eq}$ ). If psycho-social factors are also meant to be taken into account, the CVM is appropriate. For the 5 dB(A)-classes from 50 dB(A) to >75 dB(A) (see the valuation chapter 2.4), the number of people exposed along each of the specific route segments has to be calculated using an Excel-based computer model.

For road emissions daytime and nighttime noise emission levels per hour (L) in dB(A) are calculated for each route segment following the German traffic noise protection ordinance 16.BImSchV 1990 (BMV, 1990).

$$L = L_{eq}(\text{metre})(DTV/h ; \% \text{ of trucks}) + D_v + D_{surf} + D_{slop} + D_{wall} \quad (1)$$

$$\text{Leq (25)} = 37.3 + 10 \lg (\text{DTV/h} (1+0.082*p)) \text{ dB(A)} \quad (2)$$

The basis of the calculation is the equivalent sound level (Leq) measured at a distance of 25m from the emission source. It provides an average burden value per hour for day and night. The Leq (25) is a function of the Average Daily Traffic per hour (DTV/h) and the percentage of trucks (p). The following route-specific information is taken into account in the form of adders to the standardised Leq (25):

- Speed, traffic situation (Dv)
- Road surface (Dsurf)
- Slope of the segment (Dslop)
- Noise reduction facilities (screens, walls, etc.) (Dwall)

The dispersion formula given in the German ordinance provides dB(A) values which reduce the emission level L by the amount of Ddist.

$$\text{Ddist} = 15.8 - 10 * \lg (d) - 0.0142 (d)^{0.9}, \quad d = \text{distance in metre} \quad (3)$$

Free dispersion is assumed. One exception: tunnels reduce noise emissions to the level of zero. For Switzerland we have bottom-up data including information about the location of road tunnels. For the other countries involved in our route no tunnels are assumed.

The influence of the geographical and meteorological situation is not included, because no data is available. In Switzerland in particular an underestimation of external noise costs may be the consequence, because in valleys noise nuisance is partly four times higher than average.

Building up a matrix for various distances, we get a range of 10m strips along the route which are polluted with certain noise levels and can be clustered in the necessary decibel-classes. The metres exposed of each dB(A)-class are multiplied by the segment-related persons per metre value, which was derived from population density (pers/km<sup>2</sup>) data. Again, data for population around the motorway are calculated by using district data in Germany, canton data in Switzerland, and regional data in Italy.

Concerning rail traffic the main assumption made is that passenger trains run only in the daytime (06.00 to 22.00), freight trains only at night (22.00 to 06.00). According to 16. BImSchVO §3 Anlage 2 (BMV, 1990) we calculate for each train technology and route segment a noise emission level per hour (L) in dB(A).

$$L = \text{Leq (trains/h ; \% of disc-braked waggons)} + \text{Dvl} + \text{Dwall} (+ \text{Dtrack}) \quad (4)$$

$$\text{Leq (25)} = 51 + 10 * \lg (n * (5 - 0.04 * p)) \text{ dB(A)} \quad (5)$$

The basis of the calculation is the equivalent sound level (Leq), which provides an average burden value per hour for day and night at a distance of 25m from the middle of the track. The Leq is a function of the number of trains/h (n) and the percentage of disc-braked waggons (p) (of the total train). Route-specific information can be taken into account in the form of adder to the standardised Leq (25):

- speed and length of the train (Dvl)

- noise reduction facilities (screens, walls, etc.) (Dwall)
- track surface (Dtrack) (no data available).

Regarding these route-specific characteristics, we get an emission level for each segment divided by class of train. Following the German ordinance, we add these up the technology-specific sound levels to a total emission level for each segment:

$$L_{total} = 10 \lg (100.1 * L_1 + 100.1 * L_2 + 100.1 * L_3 + 100.1 * L_4), \quad (6)$$

where L1 is the highest (e.g. the ICE-) and L4 the lowest sound level.

We assume for road and rail transport that roads and railway tracks run exactly parallel. Hence the above mentioned characteristics of dispersion also apply to rail traffic.

In this paper aircraft noise cannot seriously be taken into account due to problems with the specification of the duration and the location of the sound around the airports concerned. Besides, the method for measuring aircraft noisetakes peak sound levels into account and differs from the road/rail method (continuous noise sources).

### 3.5 Accidents

From the literature on economics, we know that the accident costs which are relevant for the pricing of infrastructure use can be defined as the difference between marginal social and marginal private accident costs, which is called marginal external accident costs. Due to our empirical bottom-up approach the calculation starts by counting the number of accidents on our route in 1995 for each mode divided according to passenger and goods transport. These accidents are valued with the recommended monetary values minus the part which is covered by insurances.

Formally we can express the total external accident costs (AC) for each transport mode as follows:

$$AC = \sum_{j=1}^2 \sum_{n=1}^3 v^n * (1 - c^n) * A_j^n \quad (7)$$

Index  $j$  represents the distinction between passenger and goods transport (for road traffic: car accidents or truck accidents). Index  $n$  indicates the severity of the accident. We differentiate between fatalities, serious and minor injuries from accidents. Variable  $A$  represents the number of persons (for each severity class) involved in the accidents.  $v$  represents the recommended monetary values for each severity class, while  $c$  indicates the percentage by which the valuation function is reduced due to the already internalised accident costs borne by the health insurance companies and employers' liability insurance associations.

This approach is independent of the traffic volume (vehicle km travelled), thus, marginal costs in dependence of the traffic flow cannot be calculated. However, Jansson indicates that for interurban traffic the accident rate is more or less independent of the traffic flow (PETS, 1997). In other cases, if no real data is available, a risk approach has to be applied including the probabilities that accidents of every severity occur (for an example see Mayeres *et al*, 1996).

With regard to road traffic a difficulty arises when we try to distinguish between accidents related to cars and trucks. From the German Statistical Office (1995) we know the number of one-vehicle and two (or more)-vehicle accidents. It is the latter ones that are critical. The assumption was made that all accidents involving trucks are subsumed under the category "truck accidents" even if cars are also involved.

On our route there were no train or plane crashes causing fatalities or injured persons in 1995 (German Bundesbahn, 1997; German Lufthansa, 1997). Thus, for these transport modes the external accident costs are zero. One could argue that in this case a risk approach seems to be appropriate. However, due to the lack of probability data for each transport mode on our route, the application of a risk-based method would not be serious.

#### 4 RESULTS FOR THE ROUTE FRANKFURT - MILAN

Due to limited space, not all the specific calculation steps and results for the route Frankfurt - Milan can be presented in this paper. Therefore, we will concentrate on results which allow a modal comparison for passenger and goods transport. In the QUITTS final report the results from each step of the process of identification, quantification and valuation of external effects are documented separately to make the assumptions transparent and to provide all relevant information for decision-makers (see Weinreich *et al.*, 1998).

Concerning road traffic, our route has a length of 634.8 km including the motorway A5 from Frankfurt to Basel (310.1 km), the A2 from Basel to Como (282.7 km) crossing the St. Gotthard pass, and the A8/9 from Como to Milan (42 km). An average occupancy factor for the whole route for long-distance traffic is assumed which is usually higher than the average factor including short and long distances. For cars, an average occupancy factor of 1.81 passengers per vehicle is assumed, the corresponding figure for trucks is 8.77 tonnes per vehicle.

Concerning rail traffic, the input data for the calculation of emissions and external costs was gathered from the responsible railway companies, for the route Frankfurt-Milan primarily from the German railway company (German Bundesbahn 1997). Four passenger train technologies are included, highspeed (ICE for Germany and partly for Switzerland, and one Cisalpino/day from Zurich to Milan), Intercity/Eurocity (IC/EC), Interregio, D-, and Night-trains (IR/D/N), and local trains. 183.8 passengers per train is the average occupancy of all four train technologies. For goods transport only one full load train technology (1,600 tonnes train) powered by electricity is analysed to represent this very inhomogeneous transport mode. The total route is 715 km long and is made up of 343 km in Germany (D), 326 km in Switzerland (CH), and 46 km in Italy (I).

With regard to air traffic, the average length of the flight is 535 km. Seven types of airplanes (B737, MD80, AVRA, A322, A300, A310, and A321) cover more than 98 % of all flights so that the calculations are limited to these types. In 1995 the average number of passengers per airplane was 84.3.

Table 6: Comparison of the emissions per trip from different transport modes, direction Frankfurt - Milan (one way), passengers and goods in 1995

Passengers	g/passenger-km			Goods	g/tonne-km	
	road	rail	air		road	rail
CO <sub>2</sub>	105.78	33.11	181.25	CO <sub>2</sub>	73.24	13.335
CO	2.59	0.01	0.39	CO	0.23	0.004
HC	0.15	0.00	0.06	HC	0.11	0.001
NO <sub>x</sub>	0.69	0.04	0.60	NO <sub>x</sub>	0.72	0.017
SO <sub>2</sub>	0.015	0.06	0.03	SO <sub>2</sub>	0.04	0.023

Concerning the emissions and external costs of one trip, only passenger-related or tonne-related figures are comparable, i.e. ECU/passenger or ECU/tonne and ECU/passenger-km or ECU/tonne-km. Table 6 presents the emissions per trip from different transport modes.

The external costs due to air pollutants, global warming, noise, and accidents will be compared in Table 7 for passenger traffic and in Table 8 for goods transport summarizing the results for each transport mode.

Table 7: Specific external costs of passenger road, rail and air traffic per trip, direction Frankfurt - Milan, 1995

	Air pollutants	Global warming	Noise	Accident	Total external costs
	ECU/1000 pkm				
<b>ROAD-PASSENGER</b>					
Frankfurt - Basel (D)	14.77	5.11	4.37	13.16	37.41
Basel - Como (CH)	12.98	5.17	1.82	31.63	51.60
Como - Milan (I)	34.25	5.60	7.35	27.48	74.68
Frankfurt - Milan	15.63	5.16	3.83	19.64	44.26
<b>RAIL-PASSENGER</b>					
Frankfurt - Basel (D)	2.95	2.82	2.79	0	8.56
Basel - Como (CH)	0.18	0.09	0.52	0	0.79
Como - Milan (I)	4.62	2.81	0.31	0	7.74
Frankfurt - Milan	1.71	1.54	1.62	0	4.87
<b>AIR-PASSENGER</b>					
Frankfurt - Milan	9.60	8.55	3.76*	0	21.91

For air pollutants, the figures given are calculated with the YOLL concept. For global warming, the results are based on the high value of 170 ECU/tonne of carbon. The asterisk (\*) indicates a value from IWW/Infras (1995) for Germany, as noise from air traffic is not quantified in the QUTTS project.

Regarding the Swiss route sections, the difference between road and rail traffic is enormous, because the electricity for the railway system is mostly generated without fossil fuels, which has a strong impact on both air pollutants externalities and global warming. For noise the differences between the national route sections seems to be too high; this can be explained by the limited population data available and the exclusion of valley effects. The inclusion of tunnel segments is another reason for the low Swiss noise results.

The comparison of the specific external costs also indicates that the results are route-specific. The Italian figures in particular, which refer to a very short route section 46 km in length, cannot be seen as averages for the whole country.



Table 8: Specific external costs of road and rail freight traffic per trip, direction Frankfurt - Milan, 1995

	Air pollutants	Global warming	Noise	Accident	Total external costs
	ECU/1000 tkm				
<b>ROAD-GOODS</b>					
Frankfurt - Basel (D)	14.26	3.23	8.79	2.44	28.72
Basel - Como (CH)	18.81	3.84	3.98	5.03	31.66
Como - Milan (I)	19.28	3.78	15.55	8.87	47.48
Frankfurt - Milan	15.74	3.42	7.96	3.50	30.62
<b>RAIL-GOODS</b>					
Frankfurt - Basel (D)	0.90	0.86	1.97	0	3.73
Basel - Como (CH)	0.06	0.03	0.53	0	0.62
Como - Milan (I)	1.80	1.09	1.20	0	4.09
Frankfurt - Milan	0.68	0.62	1.50	0	2.80

For air pollutants the figures given are calculated with the YOLL concept. For global warming, the results are based on the high value of 170 ECU/tonne of carbon.

Concerning the external environmental and health costs due to air pollutants, the results for cars are aggregated figures that take into account the vehicle-mix of each country involved. An approximation based on the specific emission factors is made for all major car technologies. These figures are presented in Table 9.

Table 9: Specific external environmental and health costs due to air pollutants from different car technologies per trip, direction Frankfurt-Milan, 1995.

ROAD-PASSENGER	Germany	Switzerland	Italy	Total FM
	ECU / 1000 pkm			
petrol with catalytic converter	9.1	6.2	8.6	8.1
petrol conventional	47.4	35.6	42.7	42.5
diesel	13.0	20.2	23.8	14.6

## 5 CONCLUSIONS

Finally, we are able to draw the following conclusions from the externality analysis:

- The application of the integrated model for the calculation of road-specific external costs is a first step towards the complex analysis of the dispersion of air pollutants, the identification and quantification of impacts, as well as the valuation of these impacts.
- Concerning the comparison of transport modes, external costs of passenger road traffic are about 9 times as high as those from rail traffic and about twice as high as those from air traffic. Even if we exclude accident costs which dominate the external costs of car traffic from the comparison, road traffic results for the whole route are about 5 times as high as those from rail traffic. For goods transport, it can be concluded that the external costs of road traffic are about 11 times as high as those from rail traffic.
- For the valuation of external costs of global warming, new estimates were used which were derived from the current ExternE study of the European Commission. The global warming damages estimated in this study are significantly higher than calculations in earlier studies. However, they are lower than estimates derived from an avoidance cost approach, which was used in some recent top-down studies (e.g. IWW/Infras 1995).

- For noise impacts it can be concluded that there are great differences between the national route sections due to different population densities along the route. Besides, the inclusion of tunnel segments (noise dispersion is set to 0) is a reason for the low Swiss noise results.
- The bottom-up approach for the route-specific external cost analysis produces plausible results. In comparison to top-down approaches the results are about twice as high for passenger road transport with regard to external environmental and health costs due to air pollutants. 99.2 % of the external costs of road traffic are due to health damages caused by air pollutants, only 0.8 % are caused by impacts on crops, forests and material. This can be explained by the high mortality impacts of air pollutants in the current EcoSense version.
- With regard to impacts of air pollutants, some sensitivity analyses were made. This is particularly important in order to show the sensitivity of results to the use of alternative concepts for valuing health risks (YOLL vs. VSL approach). It can be concluded that the total external costs as well as the specific ones double when the VSL concept is applied.

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**A POLICY-SENSITIVE FORECASTING SYSTEM FOR  
EVALUATING THE  
ECONOMIC AND ENVIRONMENTAL EFFECTS OF  
MEASURES TO REDUCE AIRCRAFT EMISSIONS**

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**Abstract:**

Continuing growth in civil aviation activity may be having adverse impacts on global warming and UV radiation due to aircraft emissions in the upper atmosphere. Recognising this, but that mitigating measures might themselves have adverse economic implications for the aviation industry and national economies, the Dutch government commissioned Project AERO (Aviation Emissions and Evaluation of Reduction Options) to find the "best" strategy to reduce air traffic effects on the atmosphere, by weighing the environmental benefits against the economic consequences. Project AERO has created a forecasting system of future world-wide aviation activity, with its environmental and economic impacts, to test a wide range of fiscal and regulatory measures that might reduce aircraft emissions, and to establish trade-offs between environmental effectiveness and the economic consequences for airlines, users and governments. The system's forecasts are largely driven by demand growth, but costs imposed on airline operation by policy measures are modelled to feed back to fares, and hence restraint of demand growth, capacity provided and airline profitability. Aircraft technology development is explicitly represented, and emission volumes, their spatial distribution and atmospheric impacts are also modelled. The paper describes the AERO system and presents preliminary results of policy tests.

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## 1 INTRODUCTION

There is increasing concern that the continuing growth in aviation activity - typically at 5% per year - is having adverse impacts in the upper atmosphere due to aircraft emissions of NO<sub>x</sub>, CO<sub>2</sub>, hydrocarbons, etc. Recognising this concern, and also that measures to mitigate the environmental impacts might themselves have adverse economic implications for the aviation industry and their economy, the Dutch government commissioned Project AERO (Aviation Emissions and Evaluation of Reduction Options) with the remit to find the "best" strategy to reduce the impacts of air traffic on the atmosphere, by weighing the environmental benefits against the economic consequences.

The main feature of Project AERO has been the development and application of a policy-testing information and forecasting system of future world-wide aviation activity, with its associated atmospheric emissions and economic impacts. The AERO Information and Modelling System - AIMS - has been set up in a robust and user-friendly computing environment, so that policy analysis can be carried out efficiently and confidently in-house by Dutch government staff.

AIMS is exceptional among air traffic modelling systems in that aviation demand forecasts, sensitive to economic growth and air transport prices, are the key driving force behind estimates of future air traffic in both the presence and absence of emissions-related policy measures. The chief outputs of AIMS are:

- the volume and three-dimensional spatial distributions of aircraft emissions in the atmosphere, and their environmental impacts;
- the costs and revenues, and hence financial results, of airlines at a world-region level.

The purpose of this paper is to describe the functionality of AIMS and present results from policy tests carried out with AIMS. The remainder of this paper elaborates on the environmental problems related to aircraft engine emissions (chapter 2); the analytical approach followed in AIMS including an overview of the system (chapter 3); the individual models included in AIMS (chapter 4); calibration and scenario results (chapter 5); and finally preliminary results related to policy-testing (chapter 6).

## 2 ENVIRONMENTAL PROBLEMS RELATED TO AIRCRAFT EMISSIONS

### 2.1 Overview

Aircraft engine emissions include CO<sub>2</sub>, NO<sub>x</sub>, CO, C<sub>x</sub>H<sub>y</sub>, SO<sub>x</sub>, H<sub>2</sub>O and soot. Table 2.1 shows that these emissions relative to total global emissions from human sources are currently small, but their contribution is growing as air traffic increases. Moreover, they are the only direct human source of emissions in the upper atmosphere. There is increasing concern, therefore, that aviation activity may add to global warming, air pollution and UV radiation.

Table 2.1 Emissions from commercial aircraft engines compared to global emissions from human sources

Substances	Units	Total emissions from human sources	Aircraft engine emissions	Contribution of aircraft engines (%)
CO <sub>2</sub>	Mton	29.10	0.45	1.56
NO <sub>x</sub>	Kton	100.21	1.84	1.80
So <sub>x</sub>	Kton	148.43	0.13	0.09
C <sub>x</sub> H <sub>y</sub>	Kton	320.75	0.40	0.12
CO	Kton	973.99	0.99	0.10

Source: EDGAR database (RIVM) and computations with AERO modelling system

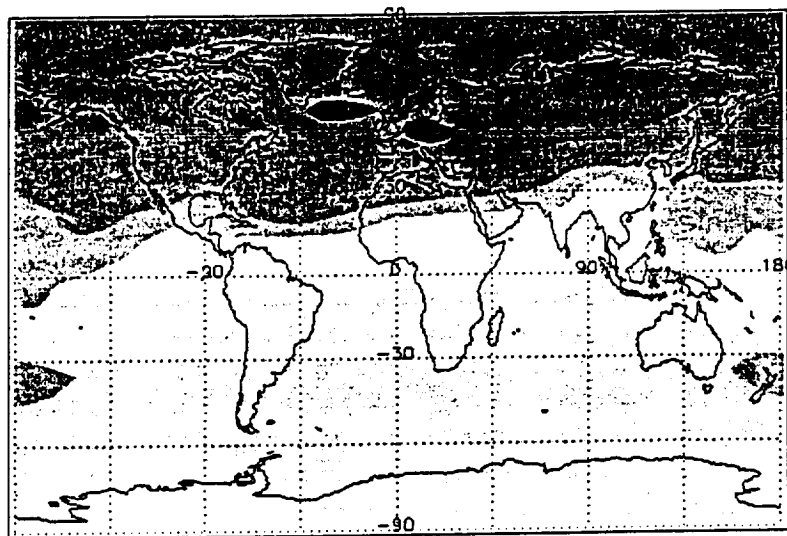
## 2.2 Climate Change

Aircraft engine emissions-related contributions to climate change may include:

- a direct contribution to radiative forcing of greenhouse gases;
- the effect of NO<sub>x</sub> on ozone formation in the lower atmosphere, also leading to an increase of radiative forcing;
- the effect on radiative forcing of SO<sub>x</sub>, H<sub>2</sub>O and soot at high altitudes.

CO<sub>2</sub> is generally considered to be the most important greenhouse gas, contributing more than 60% to the radiative forcing effect compared to pre-industrial values (IPCC, 1995). The impact of CO<sub>2</sub> is aggravated by its very long atmospheric life. However, there is now evidence that the indirect radiative forcing effects of water, aerosol and particulate emissions of aircraft engines may be as large as those from their contribution of CO<sub>2</sub>.

Figure 2.1 Contribution of aircraft emissions of NO<sub>x</sub> to NO<sub>x</sub> concentrations at cruise level (max. 57%) based on the situation of 1992.



100%

50%

0%

Source: Computations with AIMS



The contribution of aircraft engine emissions of NO<sub>x</sub> to radiative forcing by tropospheric (lower atmosphere) ozone formation may also be of the same order as their emissions of CO<sub>2</sub>. (Friedl et al., 1997). This is due to the sensitivity of radiative forcing to the ozone content at altitude bands between 8 and 12 km, where most of aviation activity takes place. Figure 2.1 shows that aircraft engines at cruise level (around 10 km or 35000 feet) presently (1992) contribute more than 50% to NO<sub>x</sub> concentrations at certain locations in the Atlantic corridor.

### 2.3 Air Pollution

Aircraft engine contributions to ground level air pollution mostly follow from the emission of NO<sub>x</sub>. The distribution of aircraft NO<sub>x</sub> emissions across a range of altitude bands, as computed by AIMS, is shown in Table 2.2, where it can be seen that less than 30% of these emissions take place below 5000 m. This, and the short NO<sub>x</sub> lifetime, implies that from a global perspective aircraft NO<sub>x</sub> emissions effectively do not contribute strongly to ground level NO<sub>x</sub>, and hence to smog formation or acidification.

*Table 2.2 Distribution of NO<sub>x</sub> emissions from aircraft engines by altitude band*

Altitude band	Relative distribution of NO <sub>x</sub> emissions	
	By altitude band	Cumulative across altitude bands
0 - 1000 m	16.4%	16.4%
1000 - 2000 m	3.7%	20.1%
2000 - 3000 m	3.3%	23.3%
3000 - 4000 m	2.9%	26.2%
4000 - 5000 m	2.6%	28.9%
5000 - 6000 m	2.6%	31.4%
6000 - 7000 m	2.9%	34.4%
7000 - 8000 m	3.1%	37.4%
8000 - 9000 m	2.9%	40.4%
9000 - 10000 m	10.1%	50.4%
10000 - 11000 m	30.3%	80.7%
11000 - 12000 m	17.3%	98.0%
> 12000 m	1.9%	100.0%

Source: Computations with AIMS

### 2.4 UV Radiation

Stratospheric (upper atmosphere) ozone depletion increases UV penetration, with its attendant environmental and health dangers. NO<sub>x</sub>, SO<sub>x</sub> and soot emissions may contribute to stratospheric ozone depletion. While it is believed that aircraft flying in the troposphere do not affect stratospheric ozone levels, the increasing altitudes at which aircraft cruise is heightening concern over aviation's part in ozone damage. (NASA, 1996).

### 3 ANALYTICAL APPROACH AND OVERVIEW OF SYSTEM

#### 3.1 Basic Approach

In analysing the effects of Policy measures, the approach of AIMS is to make a very clear distinction between a Datum scenario - a User-defined specification of the future, excluding Policy measures - and a Policy forecast - the estimated outcome of imposing measures in the Datum scenario. The overall structure of AIMS was created around this distinction.

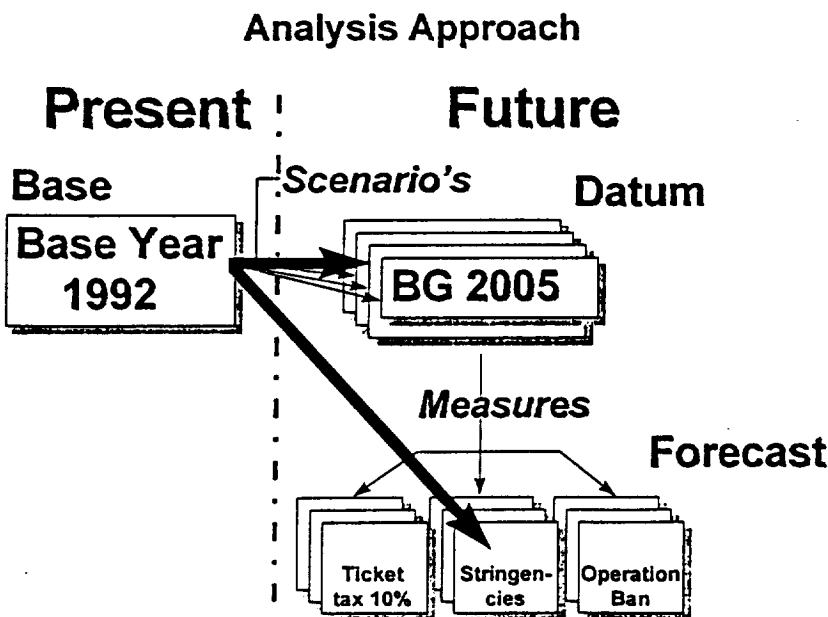
The structure comprises three fundamental steps (see Figure 3.1). The first involves a description (in the Unified Database) of Base-year aviation activity (1992), in terms of civil aircraft movements, passenger and cargo demand by flight stage.

The second step sets up the Datum scenario. The User's input assumptions - such as economic growth rates, real changes in fare levels, and technological development - are translated by AIMS into changes in aviation activity between the Base-year and a future year for which forecasts are required.

In the third step, the User introduces the Policy measures to be tested, within the context of the Datum scenario. AIMS estimates the differences in aviation activity that would result from the measures compared to the Datum position.

To establish the merit of alternative Policy measures requires the third step to be compared with the second. Clearly, the impact of measures may change if the Datum scenario is changed. It is therefore important that the User can test the effects of measures within alternative scenarios: that is, within alternative views of the future (without measures).

Figure 3.1 Overview of AERO analysis approach



AIMS requires the User's input to set up the Datum scenario. This is performed through a User-Interface by selecting a pre-defined scenario (though the User can check its assumptions), by modifying an existing scenario, or by creating a scenario from scratch.

### **3.2 Effects of Policy Measures and Treatment of Technology Change**

Among the Policy measures which the AIMS-User can test are:

- taxation on fuel, landing charges, and passenger tickets
- subsidies towards purchase of new aircraft
- global or regional bans on operations by older-technology aircraft
- imposition of more stringent engine-emission restrictions for new aircraft designs
- improvements in air traffic control (reduced congestion)
- measures imposed selectively on EU airlines
- measures imposed only on air traffic to and from the Netherlands.

The main effect of most Policy measures is expected to be a lower level of aviation activity than would be the case without the measures (rather than technology shifts). This would probably manifest itself as slower growth in activity through time.

Based on the comparison of alternative futures (with Policy measures compared to the Datum without measures), typically the process for (say) a tax imposed on aircraft fuel would be:

- the fuel tax increases airline operating costs
- airlines (seek to) pass on the increase in costs in terms of higher passenger fares and freight rates
- higher fares and rates depress (growth in) demand
- capacity offered is correspondingly lower (ie grows less rapidly)
- emissions are thereby lower (than they would otherwise have been).

Relative to this process, the effect on emissions of shifts in technology - compared to what would otherwise have been the case - will be secondary. Nonetheless, AIMS allows that (to continue the example) higher fuel prices (due to the tax) will provide an incentive to airlines to shift more strongly to more fuel-efficient aircraft than they otherwise would have; this would reduce the impact of the tax on operating costs, and the consequent effects on fares and rates, demand and capacity would be smaller than without the technology shift.

Changes in aircraft technology through time can be specified by the User as part of the Datum scenario.

### **3.3 Overview of the AERO Information and Modelling System**

AIMS covers a sequence of steps from the description and generation of aviation demand to the assessment of the environmental impacts of aviation emissions. These steps are formulated through the use of a Unified Database and the following nine linked models:

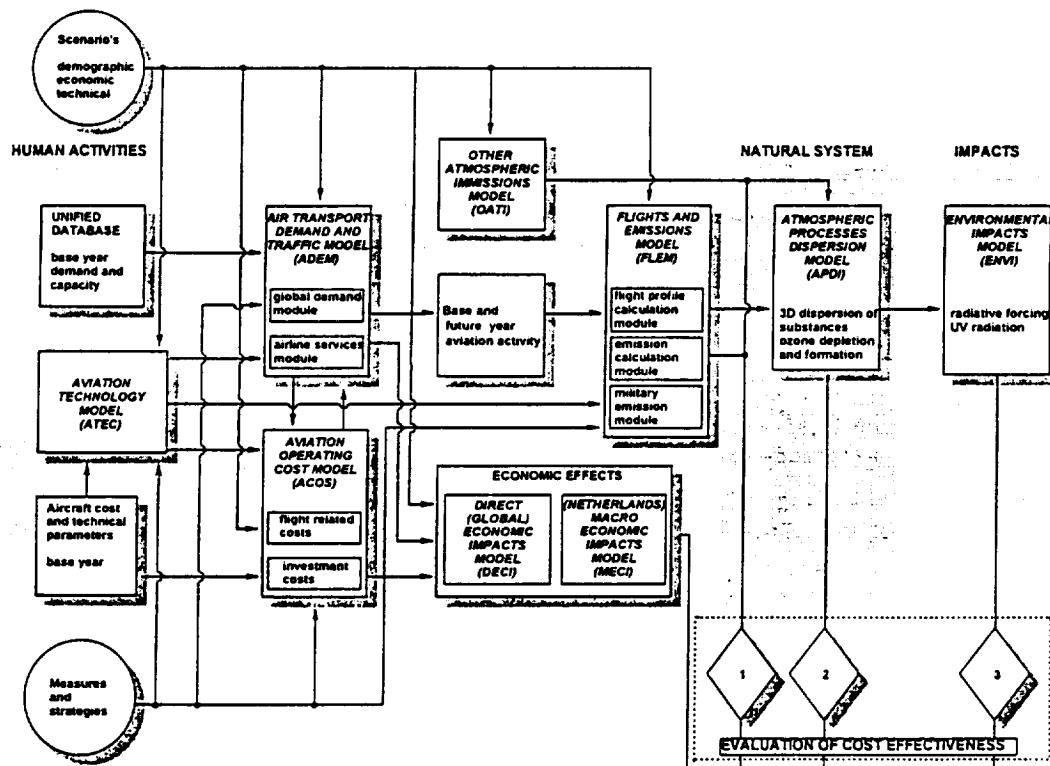
- 1 ATEC Aircraft technology model

2	ACOS	Aviation operating cost model
3	ADEM	Air transport demand and traffic model
4	DECI	Direct economic impacts model
5	MECI	Macro-economic impact model for the Netherlands
6	FLEM	Flights and emission model
7	OATI	Other atmospheric immissions model
8	APDI	Atmospheric processes and dispersion model
9	ENVI	Environmental impact model

A complete overview of the AERO information and modelling system is presented in Figure 3.2. A further description of the Unified Database and the 9 models is given in chapter 4.

All the components of AIMS - models, input data, system assumptions, User inputs and modelled outputs - are embedded in a software shell. The main functions of the shell are to facilitate communication and interaction between the various models, and between the User and the complete AIMS system.

Figure 3.2 Overview of the AERO modelling system.



## 4 MODEL DESCRIPTIONS

### 4.1 The Unified Database

The Unified Database quantifies global aircraft movements and air passenger and cargo demand for the Base-year of AIMS. Though global in coverage, the data are spatially disaggregate. Flight stages connecting about 350 major world cities are recorded individually; other flight stages are grouped by world region, hub airport and stage length.

Within the Unified Database, aircraft movements are categorised by aircraft capacity, range, function (passenger/combi or dedicated freighter) and technology level. Movements are also classified by scheduled, charter and non-commercial. For 1992, 24 million civil flights are represented in the database.

The scheduled flight data were taken from the ICAO "Traffic by Flight Stage" (TFS) data for international movements, the US Department of Transport "T-100" data for US domestic flights, and the ABC (now OAG) timetable for scheduled movements not included in the first two sources, following elimination of double-counting (based on matching origin, destination, carrier and aircraft function). A similar elimination of double-counting between the ANCAT database and the compendium of scheduled sources was also necessary, to extract non-scheduled (mainly charter) movements from the ANCAT database.

Given the dependency of AIMS on aviation demand forecasting, a major advantage of the TFS and T-100 data sources is that they include passenger and cargo demand data, as well as aircraft movements, for the flight stages which they cover. Other scheduled flight stages drawn from the ABC timetable do not (of course) have empirical demand data; instead, these were synthesised from the load factors (by region-pair, length of haul, etc) implied by the TFS and T-100 sources. IATA data were the basis of the passenger class split for different categories of flight stage (again by region-pair, length of haul, etc).

### 4.2 Aircraft TEChnology (ATEC) Model

Model ATEC allows the AIMS-User to work with the assumption of continuously-updating technology: so-called "rolling technology". Using this concept, ATEC calculates aircraft technology indices for future years, based on the progress of technology over about 25 years up to the AIMS Base-year and on User inputs relating to technology development into the future. The indices refer to the development through time of fuel-use and emission characteristics for each generic aircraft type. A similar process applies to the prediction of new aircraft prices; in-built assumptions relate real price increases over time to the User's input scenario of the rate of technological development.

ATEC's estimates of fuel flow rates and new aircraft prices are employed by the operating cost model (ACOS), while ATEC's emission rates are used by the flight and emissions model (FLEM).

The AIMS-User can specify "certification" measures, which require that, from a specified year, all new designs of aircraft must satisfy some tighter "stringency", such as 20% lower NO<sub>x</sub> emissions than the current standard. The User defines the year and stringency level. ATEC then computes the impact of the measure on emissions per aircraft (downwards), fuel consumption (possibly upwards) and new-build prices (upwards) of the generic (ie average) aircraft of "current" technology as the new designs penetrate the aircraft fleet.

The shifts in these indices are passed to the FLEM and ACOS models, so that they can estimate the effects of the certification measure on total aircraft emissions and total operating costs. The latter will then be estimated by AIMS to have a further impact on fares, demand, capacity and movements, and hence on emissions, and airline costs, revenues and profitability.

### **4.3 Aviation DEMand and Air Traffic (ADEM) Model**

The fundamental objective of model ADEM is to forecast aircraft movements in a situation with and without measures. ADEM outputs its forecasts of aircraft movements to a database (of identical structure to the Unified Database) so that model FLEM can estimate the emissions that would arise from those movements. ADEM contributes to the accuracy with which the effects of Policy measures on emissions can be estimated by forecasting aircraft movements:

- at a high level of spatial disaggregation (individual city-pairs for the majority of seat-km)
- by aircraft type, distinguishing range, capacity and technology level.

ADEM forecasts scheduled, charter and non-commercial air traffic. The treatment of scheduled demand (passenger and cargo) and capacity is as follows.

In practice, the capacity offered on any route is an interplay of the forces of supply and demand, including the costs of operation, the fares (and freight rates) charged, the sensitivity of passenger (and cargo) demand to these, and competition between carriers. If costs are increased (through a carbon tax, for example), fares may be increased. Demand will then be lower than it otherwise would have been, as will the capacity offered. ADEM, in association with model ACOS, seeks to emulate the final position that would be reached as a result of these complex real-world interactions.

It is assumed that, at any prevailing level of fares (and freight rates), capacity will be forthcoming to satisfy passenger (and cargo) demand. Forecast aircraft movements are therefore very largely determined by forecast demand, and much of ADEM's functionality is associated with forecasting demand. This is described in more detail below.

ADEM is an incremental forecasting model. Its fundamental input is the Unified Database of passenger and cargo demand, and of aircraft movements, by city-pair in the AIMS Base-year. It then estimates changes in demand and movements arising from the Datum scenario specified by the AIMS-User. The outputs of this Datum case then become the input database for a Policy case in which the further differences in demand and movements due to Policy measures are estimated.

Economic and demographic growth rates are assumed to be the main drivers of growth in aviation traffic. Aviation demand is forecast by means of elasticities to these growth rates, calibrated from historical data. Separate growth forecasts are made for business and non-business passenger demand, and for cargo demand, because of the availability of elasticities with respect to economic growth of these categories of demand. Another vital feature of AIMS is that aviation demand is sensitive to changes in real fare levels and freight rates.

On overland flight stages of up to 700 km length, ADEM assumes that air services are faced with competition from surface modes. The effect of these is modelled in two respects. Firstly, air passenger and cargo demand elasticities are higher (more sensitive) to reflect that, if fares and freight rates are increased, there will be loss of airline traffic to the surface modes in addition to the outright suppression of traffic. Secondly the AIMS-User is permitted (as part of the Datum scenario) to assume that different extents of high-speed rail network are implemented, which increases surface competition on parallel flight stages.

As noted above, it is assumed that capacity is provided to match (in some sense) a given demand. Empirical data show that, for a given length of route, both the service frequency and the distribution of flights by size of aircraft vary systematically (on average) with the level of demand. In forecasting growth in demand on a route, ADEM also adjusts service frequency and the aircraft size distribution on the route in accordance with the empirical relationships. In this way, capacity is made to satisfy demand with realistic load factors.

The mix of aircraft (in terms of size and technology level) on a route is also modified by ADEM in response to unit cost changes resulting from measures, as estimated for each aircraft type by model ACOS. An increasing proportion of capacity is forecast to be provided by those aircraft types for which cost per unit of capacity falls most or increases least.

Most Policy measures will increase airline operating costs. The effect of the measures will depend crucially on how airlines respond to the increase in costs, and this in turn will tend to depend on the scope that carriers have - within the constraints of industry cycles and competition - to pass on higher costs in increased fares and freight rates.

As part of setting the Datum scenario, the AIMS-User can decide the extent to which carriers would be able to pass on higher costs. At one extreme, the model reflects that carriers might have to absorb the additional costs, so that fares would be unchanged (from the Datum level) and demand would consequently be unaffected. Apart from any mitigating effects of a shift in the aircraft fleet mix, the Policy measure would be predicted to have no major impact on emissions, though the profitability of airlines would deteriorate. At the opposite extreme, the AIMS-User can stipulate that carriers would be able to pass on cost increases in higher fares and freight rates to achieve the profitability per unit of capacity that is estimated in the Datum run. In this case, the Policy measure curtails growth in demand and capacity, and thus has an appreciable impact on emissions.

The foregoing presumes that, on any particular flight stage, a measure would be imposed on all carriers equally. For European policy-makers it is also important to understand the effects of imposing measures only on carriers based in the European Union (EU). AIMS

allows for such tests. Where EU carriers compete with non-EU carriers. ADEM applies the theory of Cournot oligopoly to establish the extent to which fares (common to all carriers) would be increased. This will be less than in the case where all carriers are subject to the measure. As a result, the financial position of EU carriers is forecast to deteriorate, while that of other carriers (which have the benefit of the fare increase without the Policy-induced costs) improves, thus emulating the impact on competition of discriminatory measures.

#### **4.4 Aviation COST (ACOS) Model**

The cost of providing a given level of capacity (seats, cargo space) may vary over time, and also as a result of the imposition of Policy measures. The relative cost of operating different aircraft types may also change. The main function of model ACOS is to estimate these changes in cost, which are fundamental to the forecasts of passenger and cargo demand, and aircraft movements, made by model ADEM.

On the basis of the cost changes estimated by ACOS, ADEM adjusts fares and freight rates. These influence ADEM's forecasts of passenger and cargo demand, which in turn lead to estimates of the capacity to be offered. ADEM uses the relative cost changes between aircraft types to modify the mix of aircraft (by size and technology level) through which the forecast capacity will be met. ADEM is then able to forecast aircraft movements, for which model FLEM calculates the volume and spatial distribution of emissions.

The cost changes from ACOS also contribute to the synthesis by the direct economic effects model (DECI) of the effects of Policy measures on the financial position of airlines.

ACOS estimates changes in operating costs for each of several aircraft types which are distinguished by size (capacity), range, function (passenger/combi or freighter), and technology level. The operating costs are estimated for each flight stage (city-pair, or aggregations thereof) in the AIMS database of aircraft movements.

Since AIMS employs an incremental modelling approach, forecasts of (for example) the mix of aircraft types are obtained as adjustments to a prior position, in response to changes from that position in the relative costs of different aircraft types. ACOS therefore only has to be concerned with those categories of cost which will vary over time differentially by aircraft type and/or which will be directly modified by the imposition of Policy measures, namely: i) flight crew; ii) cabin staff; iii) maintenance; iv) fuel; v) airport and navigation fees; and vi) capital charges.

Costs which do not vary with either aircraft type or Policy measure, such as general and administrative or ticket and sales costs, are excluded from ACOS, though these are subsequently treated as "volume-related costs" by DECI.

ACOS does not deal specifically with variable costs in the sense that they can be altered in the short-run; rather, ACOS estimates the differences in costs in the forecast year with Policy measures in operation compared to the same year without measures (the Datum). Carriers are assumed to have had the opportunity to adapt to the impact of Policy measures,



by - in particular - modifying the mix of aircraft types operated compared to the Datum fleet.

The cost structure for a particular type of aircraft is built up from "physical" measures and unit costs. The physical measures relate to aircraft fuel consumption rate and speed, and to flight stage distance. From these are derived block time and fuel consumption per flight for the aircraft type on the flight stage in question.

Unit costs are averaged at a region-pair level of spatial disaggregation. They relate to cycle (flight), block time or distance, depending upon the category of cost. Multiplying the physical measures by unit costs allows a cost per cycle of operating each aircraft type on a flight stage to be estimated. Dividing by aircraft size scales the cost per cycle to a cost per unit of capacity for each aircraft type.

The difference in unit costs between Datum and Policy cases (due to measures) for each aircraft type is entered into a fleet mix adjustment sub-model in ACOS. This forecasts - for each flight stage - an increase in the proportion of capacity supplied by the aircraft type(s) with the least unfavourable change in costs. The average change in costs for each flight stage will therefore be less than if the aircraft mix had remained the same. This average cost change is passed to ADEM to calculate changes in fares, with consequential effects on ADEM's forecasts of demand and capacity for each stage.

The cost changes by aircraft type are subsequently transmitted to ADEM for use in its own (identical) fleet mix adjustment sub-model. This is applied after the final capacity forecast for each stage has been estimated, and converts the capacity into movements by the revised mix of aircraft types.

#### **4.5 Direct Economic Impacts (DECI) Model**

Model DECI has three main functions:

1. post-processing traffic volume, operating cost and revenue results from models ACOS and ADEM
2. computing direct socio-economic impacts, such as airline operating results, employment, contribution to gross value-added
3. computing direct Policy impacts on aviation consumers and governments.

DECI produces a large number of output variables at global, world region and region-pair levels of spatial aggregation. This allows the AIMS-User to investigate the varying impact of Policy measures on aviation activity, airline profitability, consumers and governments by region. This is clearly important for the assessment of measures that are applied at a regional level, but global measures also can have differential impacts for different regions.

The regional breakdown of results is an important feature of DECI. Since the effects of both scenarios and measures are modelled mainly by flight stage, many of these effects are inevitably inter-regional. Using information on the proportion of airline service on each flight stage that is provided by carriers from different regions, DECI can allocate (changes

in) aviation activity, costs, revenues, subsidies, consumer benefits, etc to the airlines, their clients and governments based in individual regions.

Through the AIMS User-Interface, DECI's results are output in several standard tables. (Other information can also be readily obtained by interrogation.) These tables provide overviews of:

- cost, economic and employment information by world region and region-pair, including:
  - variable operating costs by component (see above under ACOS)
  - other (volume-related) operating costs
  - revenue tonne-km operated
  - operating revenues and operating results
  - gross value added and airline employment by category of operating staff
  - fuel consumed;
- civil aircraft fleet, classified by:
  - capacity and range capability (nine types)
  - technology level ("old" or "current")
  - function (passenger/combi or dedicated freighter)
  - global fleet, and EU carriers separately;
- impacts of Policy measures (changes from Datum position) on:
  - airlines: changes in operating costs, revenues and results
  - consumers: changes in expenditure and consumer surplus
  - governments: income from taxes and charges and outgoings due to subsidies.

The outputs facilitate comparative analysis across all cases: Base-year, Datum and Policy. The Base-year outputs can also be validated against other global and regional data sources.

#### **4.6 Macro-Economic Impact (MECI) Model for the Netherlands**

Model MECI is concerned with aviation activities at Amsterdam Schiphol airport and their socio-economic impacts for the Dutch economy. The impacts are measured in terms of (changes in) gross value added to GDP and the number of persons employed.

MECI estimates the effect on the Dutch economy of any Policy measure that the AIMS-User tests. It is particularly important, however, when measures specific to the Netherlands are being investigated, such as a fare tax being applied only to passengers using Schiphol airport. In this case, model ADEM applies higher fare elasticities to reflect that demand at Schiphol would be more sensitive to the fare tax than if the tax was applied globally. This represents the re-routing of some of Schiphol's transfer traffic via other airports (where ADEM estimates an appropriate increase in activity).

#### 4.7 FLights and Emissions (FLEM) Model

Model FLEM calculates the flight profiles of aircraft of specified type on movements between specified points (city-pairs). As a movement progresses according to its flight profile, FLEM estimates the emissions produced and distributes them across a three-dimensional grid; it also estimates fuel consumed and flight duration.

The main inputs to FLEM are various aircraft technology parameters, as previously described under model ATEC, and a traffic database of movements by generic aircraft type and technology level. In a Base-year run, movements are taken from the Unified Database; in Datum and Policy runs, the movements data forecast by model ADEM are used.

The AIMS-User can influence the flight profile calculation to test the impacts of alternative scenarios or measures, such as:

- detour factor - the extent to which shortest routes are not flown, perhaps due to increasing air traffic congestion
- altitude limit - perhaps to constrain movements to the lower atmosphere
- lift-drag factor - to simulate improvements in aerodynamic capability
- speed restrictions - to limit speeds during the cruise phase
- tankering - to simulate the carriage of fuel for return flights, perhaps due to fuel price variations between regions.

Estimated emissions for each AIMS run are accumulated by FLEM in a three-dimensional grid. Currently the spatial definition of the grid is five degrees of latitude and longitude by one kilometre of altitude. AIMS has graphical output facilities to display the emissions grid.

#### 4.8 Atmospheric models in AIMS

The atmospheric models in AIMS are:

- Other ATmospheric Immissions (OATI)
- Atmospheric Processes and DIspersion (APDI)
- ENVironmental Impact (ENVI).

Model OATI computes the emissions of non-aviation activities, including the changes in surface-transport emissions resulting from the diversion of air traffic to surface modes, as estimated by model ADEM.

The emissions estimates from the FLEM and OATI models are translated by model APDI into changes in atmospheric concentrations of relevant substances (CO<sub>2</sub>, NO<sub>x</sub> and O<sub>3</sub>). APDI is a simplified representation of the detailed Chemical Tracer Model of the Royal Netherlands Meteorological Institute.

The sequence of models in AIMS ends with model ENVI, which computes the environmental impacts - effective UV-radiation, radiative forcing - of the changes in atmospheric concentrations computed by APDI.

## 5 CALIBRATION OF BASE RESULTS AND DATUM SCENARIO RESULTS

### 5.1 Calibration of Base results

The aim, and challenge, of the calibration of the 1992 Base results was to achieve a situation where all of the key results related to aviation activity and its environmental and economic impacts simultaneously match the available real world data, within the boundary conditions imposed by internal model consistency and available input data. The key results considered in the calibration process include:

- Aviation activity parameters, i.e.:
  - o global aircraft movements, passengers and cargo transported;
  - o aircraft movements and passengers at individual major airports;
  - o global revenue tonne kilometres (RTK);
  - o data on aviation activity and economic impacts for Amsterdam.
- Global fuel use and emissions.
- Total fleet and fleet composition.
- Airline operating costs, revenues and results:
  - o airline operating costs and breakdown of relevant operating cost components;
  - o airline operating costs per revenue tonne kilometre - global and for selected routes;
  - o airline operating revenues and breakdown of relevant revenue components;
  - o airline operating results.
- Total employment and breakdown of relevant employment categories.

In a number of instances, the above process was hampered by the lack of reliable or consistent input data, where in other cases the meaning of available input data was not exactly clear. However, the final results achieved provide a coherent and consistent picture of the 1992 Base case. A selection of Base results is presented in the next section.

### 5.2 Base and Datum scenario results

A selection of Base and Datum scenario results is presented in Table 5.1. As stated above, base results have been verified against real world data. For a Datum scenario run with AIMS the User has to specify input assumptions, such as economic growth rates, real change in fare levels and technology development. In the AIMS modelling system several predefined scenarios for different scenario years are available. The Datum scenario results in Table 5.1 relate to the so-called Balanced Growth scenario. This scenario is developed by the Netherlands Central Planning Bureau. For specific aviation related developments use is made of information from other sources in order to complete the scenario for the use in AERO. The main characteristics of the Balanced Growth scenario are:

- constant growth trend for all world economies with respect to both export (driving business passenger traffic) and GNP (driving non-business passenger traffic and cargo traffic);
- fuel use of new aircraft improves by 1% per year;
- the real price of crude oil (and thereby the fuel price) increases by 2% per year;
- the real costs for cabin crew, flight crew and maintenance (per volume unit) increase in relation to economic growth:

- the real route and landing costs (per volume unit) are unchanged;
- non-variable costs and fares are adjusted such that world-wide profitability of the airline industry in the long run is approximately 2.5% (average of 1985-1995);
- surface competition is intensified for flight stages paralleling the proposed Amsterdam-Paris and Amsterdam-Frankfurt high-speed rail routes.

With respect to global aviation volume growth, Table 5.1 illustrates that aviation activities in terms of revenue tonne-kilometre (RTK) more than double in the period 1992-2005. RTK is a unit for total aviation activity, in which passenger and cargo demand are both included whereby the average passenger weight (including baggage) is assumed to be 100 kg. Also it can be seen in Table 5.1 that passenger demand grows less than cargo demand. Further the number of aircraft-km grows less than the number of passenger-km, indicating that on average aircraft will be larger in 2005.

The economic information in Table 5.1 shows that airline profitability increases from 0% in 1992 (1992 was a notoriously bad year in the airline industry) to 2.4% in 2005. As stated above a profitability of approximately 2.5% is the average long term profitability in the airline industry.

Finally Table 5.1 indicates that in the Balanced Growth scenario for 2005, global fuel use in the aviation industry grows less than the number of aircraft-km, though the average size of an aircraft will be larger in future. This improved fuel-efficiency is caused by the improvement of fuel use of new aircraft coming on the market between 1992 and 2005.

*Table 5.1 Base and datum scenario results.*

	Base 1992	Datum Balanced Growth 2005 (% change w.r.t base)
<b>Global aviation volume growth</b>		
- aircraft km per year (10 <sup>9</sup> )	20.7	65.8%
- sched. pax km per year (10 <sup>12</sup> )	1.85	88.7%
- sched. Tonne km per year (10 <sup>9</sup> )	60.8	163.1%
- RTK per year (10 <sup>9</sup> )	277	106.8%
<b>Global economic effects on airline industry</b>		
- total operation costs in US\$ per year (10 <sup>9</sup> )	227	95.3%
- total operating revenues in US\$ per year (10 <sup>9</sup> )	227	100.0%
- total result as percentage of total revenues	0.0%	*2.4%
<b>Global fuel use and emissions of aviation</b>		
- Global fuel use in kg per year (10 <sup>9</sup> )	143	45.1%
- Global CO <sub>2</sub> emission in kg per year (10 <sup>9</sup> )	451	45.1%

\* This percentage refers to the result as a percentage of the revenues in Datum.

Source: Computations with AIMS

## 6 PRELIMINARY RESULTS POLICY MEASURES

### 6.1 Introduction

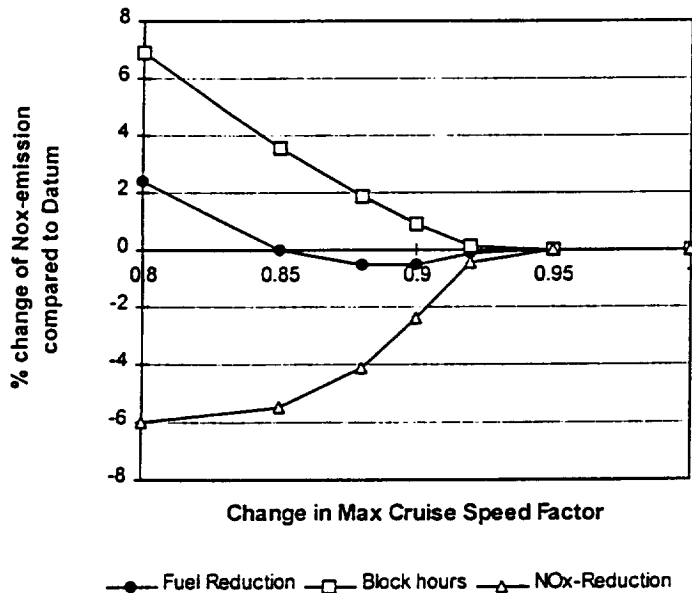
Measures can be differentiated in several categories: operational, financial, technical, regulatory, and others such as substitution by high-speed rail. Among operational measures are reductions in cruise speed and the improvement of air traffic control (ATC). Regarding financial measures, results are presented for fuel- and ticket taxes, increasing landing and en-route charges and subsidies. Technical measures such as improving the  $\text{NO}_x$ -performance and/or the fuel efficiency of engines are in practice mostly enforced by setting regulatory standards (see the ICAO stringencies for aircraft engines, by which the emissions of  $\text{NO}_x$  and other emissions are restricted).

AIMS is sufficiently developed that preliminary analyses can be executed, and some results are presented below. These results should be regarded as provisional and indicative, since model and data refinements are still in hand. All results of policy measures presented in this paper are run with the Balanced Growth 2005 scenario.

### 6.2 Operational Measures

Figure 6.1 gives the results for restricting cruise speeds. The figure shows that a cruise speed reduction of up to 15% has a small effect on fuel use (and thus  $\text{CO}_2$  emissions), but speed reductions of more than 15% increase fuel consumption.  $\text{NO}_x$  emissions decrease as speed is curtailed.

Figure 6.1 Change in global  $\text{NO}_x$ -emissions, fuel use and block hours with cruise speed



Source: Computations with AIMS

This analysis was performed with model FLEM in stand-alone mode, and thus the economic consequences of lower cruise speeds have not been determined by the full system. However, flight times obviously increase, and this will reduce the productivity of aircraft and crews. At some point costs will increase steeply, though it seems that a small restriction on cruise speed might be environmentally beneficial.

AIMS assumes that all flight distances are at least 10% longer than the shortest ("great circle") possible, due to currently-unavoidable detours and holding on airport approach. The effect of reducing detour to 5% of "great circle" distance would be major reductions in fuel consumption and related emissions, roughly equal to the fuel savings when a fuel tax of 20¢/kg is applied (see later). If ATC could be improved, the aviation sector would achieve a substantial gain (roughly 12 bn\$ pa) through the reduction in fuel costs and block hours. Since this measure has both environmental and economic benefits, it is very effective. Tests with the so-called free-flying-concept are being done and within the European Union steps are being taken to improve ATC, which could realise some of these benefits.

### 6.3 Financial Measures

Various financial measures have been proposed, with the main intention of increasing prices so that growth in demand is curbed. Several measures are compared in Figure 6.2, where the effect on airline results is plotted against the resulting fuel savings. Calculations have been made (as at 2005) for single measures, but applied globally, such as:

a fuel tax of:	5, 10, 20, 30, 50 and 100 ¢/kg;
a ticket tax of:	5, 10, 20, 30%;
an en-route surcharge of:	50, 100, 200, 300%;
an increase of the landing charges with:	20, 50, 100, 200, 300%; and
a passenger <sup>1</sup> tax of:	5, 10, 20, 30, 40 \$/pax.

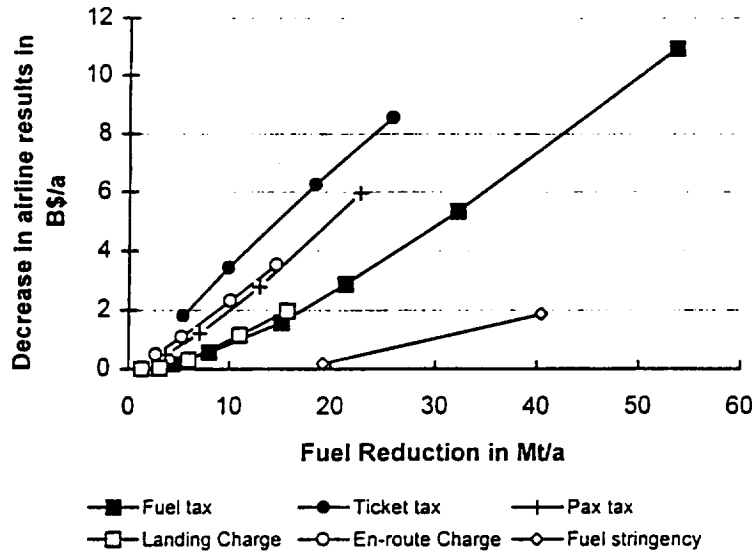
As can be seen, the fuel tax is the most efficient of these financial measures, in that it delivers the largest fuel savings at least cost. This is because airlines can use larger or more fuel efficient aircraft to reduce the cost consequences of the tax. On the other hand, a ticket tax is the most inefficient of the taxation measures as no options are open for the airlines to reduce the impact of the measure and consequently only the effect of the reduction of demand due to the higher fares remains. The other measures are in between. Using other financial indicators (such as gross value added) the conclusions remain roughly the same. The fuel stringency presented in this figure will be discussed later.

The ticket tax and the fuel tax have also been analysed, when only applied within the European Union. Provisional results indicate that under those circumstances the European carriers are more affected than their foreign competitors. If correct, this is an important conclusion, as the European Union is presently re-considering its position with respect to the current exemption for aviation to pay excise duties on kerosene.

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<sup>1</sup> This tax is applied on the passengers as a fixed fee per passenger. On this type of taxation it is assumed that the cost to fares mechanism is applicable. Contrary to the ticket tax. The ticket tax should be regarded as the European value added tax (B.T.W.).

Fig.6.2: Fuel reduction versus decrease in airline results for various taxation systems



Source: Computations with AIMS

#### 6.4 Regulation

With AIMS the effects of the  $\text{NO}_x$ -stringencies, as suggested by CAEP<sup>2</sup>, have been analysed. While the results are comparable with the results produced by CAEP, the AERO-system has also shown that costs of compliance could retard traffic growth and so lead to a substantial further reduction in  $\text{CO}_2$  and  $\text{NO}_x$ <sup>3</sup>.

So-called "propfan" engines - as partially developed during the oil crisis - have also been investigated through AIMS. There were indications that these engines had a reduced fuel consumption of up to 20%. There is not much known about their investment costs, but, since engines account for roughly 1/3 of aircraft investment costs, if propfans were 50% more expensive, then roughly with each percent increase in fuel efficiency the investment costs increase between 1 and 2%

Using these cost figures in the model a 10% increase in fuel efficiency was assumed for new aircraft that come into the market. It turns out that when the fuel savings are compared with the deterioration in airline profitability (as a consequence of the increased costs) this measure was even more efficient than a fuel tax. Further analysis (with less crude assumptions) is needed to show if this is really the case.

<sup>2</sup> CAEP: Committee on Aviation and Environmental Protection; this is a study committee within ICAO (International Civil Aviation Organization).

<sup>3</sup> This last effect was neglected by CAEP.



## 6.5 Concluding Remarks

It can be concluded that the AERO-system is an extremely versatile and powerful tool when deciding which actions to pursue to reduce the negative impacts aviation of on the atmosphere. It seems clear that the effects of operational measures to reduce detour and holdings would be effective, though other operational measures (not reported here) would not be. Technical improvements will help to reduce the emissions, but their technical and/or economic feasibility remains to be seen.

Taxation (especially on fuel) also seems a good way forward, if it is applied globally. Taxation gives a substantial reduction in fuel use and by that in emissions, the main driver being the reduction in demand growth due to the increase in fares and freight rates following from the measure. Other effects (such as encouraging more fuel efficient aircraft) are much less prominent. However, the reduction in demand, though much appreciated by environmentalists, may have a substantial negative effect on the world economy. This is not directly calculated by the AERO-system, but an indication is given by the reduction in consumer surplus for air transport users. For example, a 20c/kg fuel tax is estimated not only to reduce airline profitability by \$1.6 bn pa (see Figure 6.2) but also to reduce consumer surplus by \$36.1 bn pa compared to the case without the tax. Some 39% of the latter loss would arise in North America alone.

The AERO-system clearly demonstrates, then, that environmental gain secured by the tax might incur significant economic and social pain. It is perhaps not surprising that global taxation has a long way to go to become politically acceptable to most countries of the world (US, Russia and developing countries). There are also legal obstacles, in that almost all bilateral agreements on fuel taxation would need to be changed.

There is much further analysis to be done and creative solutions to be found to the tension between the environmental and economic impacts of continued air traffic growth, but the AERO-system provides a consistent and objective tool for this necessary and continuing investigation.

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**MODELING AIRLINE COMPETITION WITH TWO FARE CLASSES UNDER  
STATIC AND DYNAMIC GAMES (Revised Version)**

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## 1 INTRODUCTION

Since the regulations on air fares, flight frequency, and the number of airlines for each O-D market have been removed in the last decade, Taiwan's domestic air travel market has now become one of the most competitive market in Southeast Asia.

In order to assess the impact of deregulation, this paper applies game theory to seek for the strategic interaction among airlines in the oligopolistic competition environment. The strategies related to pricing include discount prices, service upgrade, and frequent flyer programs; for those related to quality of service include foods, comfort of seating, entertaining programs, reliability of schedule, baggage handling, and the frequency of direct and transfer flights. This paper focuses on the price and frequency competition of domestic airlines. Meanwhile, since the flight distances of all Taiwan's domestic routes are less than 500 miles, therefore, this paper emphasizes on direct flights only.

The objectives of this paper are as follow:

- 1) develop a mathematical model that interpret and predict the interaction among airlines in the competition market.
- 2) provide a guideline for airlines in the decision of prices and frequency of flights.
- 3) present an analytical tool for policy makers in the impact assessment of deregulation.

## 2 LITERATURE REVIEW

In the studies of oligopolistic market behavior, the most often referred models are the Cournot model, the Bertrand model, and the Stackelberg model.

The Cournot model is also called the quantity competition model. This model assumes that two companies seek to maximize their own profit by choosing the optimal production quantities given that the quantities produced by their opponents remain constant. In other words, if the quantities produced by company A is denoted as  $q_a$ , then, the optimal quantities produced by company B denoted as  $q_b^*$  should be a function of  $q_a$ . Similarly, the optimal quantities produced by company A denoted as  $q_a^*$  should be a function of  $q_b$ . The market equilibrium can be reached if  $q_a^* = q_b^*$ .

On the other hand, the Bertrand model, which is called the price competition model, assumes that two companies seek to maximize their own profit by choosing the optimal prices given that the prices set by their opponents remain constant. It should be noted that both models assumes linear relationship between prices and quantities in the production and consumer demand functions. Meanwhile, both Cournot and Bertrand models are referred as the static game models.

As for the dynamic game model, the most commonly used is the Stackelberg model. This model often assumes that one firm is the leader and the other firm is the follower. Therefore, the leader set the price or quantity of its own, then the follower chooses its optimal price and quantity according to the price and quantity set by the leader. In other words, the quantity produced by the follower, denoted as  $q_f$ , is a function of the quantity produced by the leader, denoted as  $q_l$ . Since  $q_f = f(q_l)$ , the leader can then chooses the

optimal quantity  $q_i^*$  with the predicted quantity  $q_j^* = f(q_i^*)$  that yields the maximum profit for the leader.

Meanwhile, the game theory can be viewed as an extension of the above models. First, the number of players, i.e., the competitors, is unlimited; second, the rules of the games are more flexible. For instance, if each airline knows the payoff functions of the other opponents and is capable of predicting the actions taken by his opponents, then it is called a game with complete information. On the contrary, if the information regarding to opponent's payoff function is uncertain, then it is called a game with incomplete information (Gibbon, 1992).

The game theory seeks to reveal the behavior of all players under market equilibrium, if equilibrium does exist. The market equilibrium in the game theory, often referred as Nash equilibrium, is defined as the best response for each airline given the predicted actions of the other airlines. A static game, such as Cournot and Bertrand models, means that all airline choose their strategies simultaneously, in other words, they compete on the same basis. On the other hand, a dynamic game assumes that one airline may choose its best strategy when its opponent's reactions are known. For example, Stackelberg model of duopoly assumes that the market followers would response to the actions taken by the market leader.

Although the game theory and other oligopolistic models were widely applied in the fields of economics and marketing researches, only a few applications had been done in transportation studies. One of them is the study of airline competition in a hub-and-spoke environment by Hansen (1990).

The major assumptions of his study are as follow:

- 1) each airline seeks to maximize its own profit given that the responses of all other opponents are known;
- 2) air fare and frequency are treated as separate decision variables;
- 3) business and leisure travelers have the same elasticity related to price and frequency;
- 4) the opportunity costs of airplane routing is not included in the cost function;
- 5) the capacity of airport is unbounded.

The first assumption is the basic idea of static games, the second one is a contrast to the traditional oligopolistic models which assumes that prices and quantities are mutually affected in the market equilibrium; and the third assumption is derived by the fact that Hansen applied only one air fare, i.e., the average air fare, in the formulation of the payoff function. The fourth and the last assumptions are the common restrictions to this approach since the problem is rather demand oriented than supply oriented. His study provided analytical tools for the interpretation of interaction among airline under hub-and-spoke environment. This paper is based on his work but removes the first and third assumptions. In addition, a convexity analysis and a new solution algorithm is presented to this problem.

### **3 MODEL DEVELOPMENT**

The model developed in this paper is described in three parts: 1) basic model assumptions; 2) formulation of the payoff function; and 3)-concavity analysis of the problem.

### **3.1 Basic model assumptions**

There are several assumptions of the model which are described below:

- 1) each airline seeks to maximize its own profit given that the payoff functions of all other opponents are known, but the reactions from the players may not be all simultaneously;
- 2) all flights are direct, therefore, the demand of an O-D market is independent of the other O-D pairs;
- 3) airfare and frequency are treated as separate decision variables;
- 4) the capacity of airport is unbounded;
- 5) the opportunity costs of airplane routing is not included in the cost function;
- 6) business and leisure travelers may have different tastes regarding to airfare and frequency, therefore, they should be treated separately.

The first assumption states the rules to be static or dynamic games with complete information. The second assumption addresses the fact that the method developed in this paper will be limited to the applications of direct flight market. The third, the fourth and the fifth assumptions are the same as those in the study by Hansen (1990). The third assumption, however, can be easily released in the future study if a heuristic is developed to solve the competition problems sequentially. The fourth assumption is often replaced by setting constraints on airlines' frequencies. The fifth assumption can be released if a heuristic is developed to incorporate airline routing problem in future research. The last assumption implies that leisure and business trips would be treated as separate markets in this paper. Currently, all the assumptions are applied to the paper to simplify the analysis of the problem.

### **3.2 Formulation of the payoff functions**

The payoff function, a terminology used in the game theory that represents the net profit of an airline in this study, consists of three parts: 1) the air travel demand model of an O-D market; 2) the market share function of an airline; and 3) the cost function of an airline. The description of these functions are stated below:

#### **3.2.1 The air travel demand model of an O-D market**

The demand models are formulated as two separate functions to incorporate the variation of tastes for the leisure and business travelers. The leisure travelers are often assumed to be more sensitive to changes of airfares and incomes since most of their trips are planned in advance. For instance, if the airfares increased or the depreciation of local currency caused the shrinkage of incomes, these travelers might cancel their trips. The business travelers, on the other hand, are assumed to be more sensitive to frequency rather than airfares and personal incomes since the expenses are often paid by their company and usually these trips cannot be canceled.

In addition, the travel time and fares of the other competing modes of travel should be

included in the model. Based on previous study done by Wu (1990), the formulation of the air travel demand models for two separate markets are presented as follow:

$$\ln Q_{ij}^1 = \ln \alpha_0^1 + \alpha_1^1 \ln POP + \alpha_2^1 \ln INC + \alpha_3^1 \ln AF + \alpha_4^1 \ln HF + \alpha_5^1 \ln RF \quad (1)$$

$$\ln Q_{ij}^2 = \ln \alpha_0^2 + \alpha_1^2 \ln POP + \alpha_2^2 \ln Af + \alpha_3^2 \ln AT + \alpha_4^2 \ln HT + \alpha_5^2 \ln RT \quad (2)$$

Where,

- $Q_{ij}^1$  = the volume of leisure trips by air between cities  $i$  and  $j$ ;
- $Q_{ij}^2$  = the volume of business trips by air between cities  $i$  and  $j$ ;
- $POP$  = the total population of cities  $i$  and  $j$ ;
- $INC$  = the average incomes of cities  $i$  and  $j$ ;
- $AF$  = the average airfare between cities  $i$  and  $j$ , often weighted by market shares;
- $HF$  = the bus fare between cities  $i$  and  $j$ ;
- $RF$  = the train fare between cities  $i$  and  $j$ ;
- $AT$  = the travel time by air between cities  $i$  and  $j$ ;
- $HT$  = the travel time by bus between cities  $i$  and  $j$ ;
- $RT$  = the travel time by train between cities  $i$  and  $j$ ;
- $Af$  = the frequency of flights between cities  $i$  and  $j$ ;

It should be noted that the functional forms of the air demand models are log-linear, which implies that the models could be calibrated by using the time series data provided by Taiwan's Bureau of Civil Aviation (1996). If the survey data of individual behavior is available, the demand model can be formulated as a modal choice model using techniques derived from discrete choice analysis (Ben-Akiva, 1985).

### **3.2.2 The market share models**

This model describes how travelers choose the airlines to fly. Therefore, it should include all the attributes related to the quality of service and airfares. The formulation of the model is shown below:

$$S_{ij}^{m1} = \frac{e^{V_{ij}^{m1}}}{\sum_{n=1}^N e^{V_{ij}^{n1}}} \quad (3)$$

$$S_{ij}^{m2} = \frac{e^{V_{ij}^{m2}}}{\sum_{n=1}^N e^{V_{ij}^{n2}}} \quad (4)$$

Where,

- $S_{ij}^{m1}$  = the market share in the leisure travels for airline  $m$  between city  $i$  and  $j$ ;
- $S_{ij}^{m2}$  = the market share in the business travels for airline  $m$  between city  $i$  and  $j$ ;

$N$  = the number of airlines served between city  $i$  and  $j$ ;

$V_{ij}^{m1}$  = the utility function of the leisure travel for airline  $m$  between city  $i$  and  $j$ ;

$V_{ij}^{m2}$  = the utility function of the business travels for airline  $m$  between city  $i$  and  $j$ ;

Equations (3) and (4) show that the market share model are formulated as multinomial logit model (Ben-Akiva, 1985). The variables of the utility functions often consist of the airfares and frequency of all competing airlines, and the airline-specific constant, which represent the quality measures of these airlines. The functional forms of these utility functions are as follow:

$$V_{ij}^{m1} = \beta_{11} F_{ij}^{m1} + \beta_{21} \ln v_{ij}^m + c_{m1} \quad (5)$$

$$V_{ij}^{m2} = \beta_{12} F_{ij}^{m2} + \beta_{22} \ln v_{ij}^m + c_{m2} \quad (6)$$

Where,

$F_{ij}^{m1}$  = the average air fare of airline  $m$  for leisure travelers between city  $i$  and  $j$ ;

$F_{ij}^{m2}$  = the average air fare of airline  $m$  for business travelers between city  $i$  and  $j$ ;

$v_{ij}^m$  = the frequency of flights of airline  $m$  between city  $i$  and  $j$ ;

$\beta_{11}, \beta_{21}$  = the model parameters in the utility function of the leisure travelers;

$\beta_{12}, \beta_{22}$  = the model parameters in the utility function of the business travelers;

$c_{m1}$  = the specific constant for airline  $m$  in the utility function of the leisure travelers;

$c_{m2}$  = the specific constant for airline  $m$  in the utility function of the business travelers.

It should be noted that only  $(N-1)$  airline-specific constants could be calibrated in the model. Meanwhile, the marginal utility of flight frequency should decrease as frequency increases, therefore, the variable of frequency has the logarithm form in the utility function.

### **3.2.3 The cost functions**

The costs of a one-way flight are often addressed in two parts, the fixed costs, and the variable costs. The fixed costs include the fees of airports and other administration costs. The variable costs include the costs of fuel and labor, which should vary with flight distance and aircraft types. Although the cost data are often confidential, there are some good estimates of these costs, which can be found in official reports. By using the rule of thumb, the cost function is assumed be a linear function as follows:

$$C(v_{ij}^m) = C_{ij}^m \times v_{ij}^m \quad (7)$$

Where,

$C_{ij}^m$  = the estimated costs of a one-way flight for airline  $m$  between city  $i$  and  $j$ .

Combining equation (1) to (7) produces:

$$\pi_{ij}^m = \sum_{k=1}^2 Q_{ij}^k \times S_{ij}^{mk} \times F_{ij}^{mk} - C_{ij}^m \times v_{ij}^m \quad (8)$$

Where,

$\pi_{ij}^m$  = the payoff function of airline  $m$  for the air travel market between city  $i$  and  $j$ .

### 3.3 Concavity analysis of the payoff functions

Since the first assumption of the model states that each airline seeks to maximize its own payoff, it is necessary to explore the concavity of the payoff functions with respect to the decision variables, i.e., air fares and frequency. Let's focus on these two variables, then for one O-D market, equation (8) can be rewritten without the notation  $ij$  as follows:

$$\pi^m = \sum_{k=1}^2 Q^k \times S^{mk} \times F^{mk} - C^m \times v^m = \sum_{k=1}^2 e^{A_k + B_k} \times \frac{e^{\beta_k F^{mk} - \beta_{2k} \ln v^m + c_{mk}}}{\sum_{n=1}^N e^{\beta_k F^{nk} + \beta_{2k} \ln v^n + c_{nk}}} \times F^{mk} - C^m \times v^m \quad (9)$$

where,

$$A_1 = \ln \alpha_0^1 + \alpha_1^1 \ln POP + \alpha_2^1 \ln INC + \alpha_4^1 \ln HF + \alpha_5^1 \ln RF$$

$$B_1 = \alpha_3^1 \ln AF$$

$$A_2 = \ln \alpha_0^2 + \alpha_1^2 \ln POP + \alpha_2^2 \ln AT + \alpha_4^2 \ln HT + \alpha_5^2 \ln RT$$

$$B_2 = \alpha_2^2 \ln Af$$

Suppose that

$$AF = \sum_{n=1}^N \sum_{k=1}^2 a^{nk} F^{nk} \quad (10)$$

$$Af = \sum_{n=1}^N b^n v^n \quad (11)$$

where,

$a^{nk}$  = the weight of the fare class  $k$  for airline  $n$ ,

$b^n$  = the weight of the frequency for airline  $n$ .

Then,  $B_1$  and  $B_2$  contain the variables airfare and frequency, respectively.

#### 3.3.1 Concavity of payoff functions with respect to airfares

The first derivative of  $B_1$  with respect to airfare  $F^{mk}$  should be  $a^{mk} \alpha_3^1 / AF$ . In other words, with the inclusion of equation (10), the first derivative of  $Q^1$  becomes:



$$\frac{\partial Q^1}{\partial F^{mk}} = a^{mk} \alpha_3^1 (AF)^{\alpha_3^1 - 1} = a^{mk} \alpha_3^1 (F^{1mk} + a^{mk} F^{mk})^{\alpha_3^1 - 1} = \delta^{mk} (F^{mk})^{\alpha_3^1 - 1} + F_p^{mk} \quad (12)$$

where,

$F^{mk}$  = the weighted average of airfares except  $F^{mk}$ ,

$a^{mk}$  = the coefficient of  $F^{mk}$ ,

$F_p^{mk}$  = the remaining polynomials with order less than  $(\alpha_3^1 - 1)$  in equation (11a).

Denote

$$\pi^m = \pi^{m1} + \pi^{m2} - C^m v^m \quad (13)$$

such that

$$\pi^{mk} = e^{A_k + B_k} \times \frac{1}{1 + D_k e^{-v^{mk}}} \times F^{mk} \quad (14)$$

where,

$D_k$  = the sum of the denominator except  $e^{v^{mk}}$ .

Then the first and the second derivative of the airline 1's payoff function with respect to airfare of class 1 can be written as follows:

$$\frac{\partial \pi^1}{\partial F^{11}} = \frac{\partial \pi^{11}}{\partial F^{11}} = \frac{Q^1}{1 + D_1 e^{-v^{11}}} + \frac{F^{11} \partial Q^1 / \partial F^{11}}{1 + D_1 e^{-v^{11}}} - \frac{Q^1 F^{11} D_1 \partial e^{-v^{11}} / \partial F^{11}}{(1 + D_1 e^{-v^{11}})^2} \quad (15)$$

Since

$$\frac{\partial e^{-v^{11}}}{\partial F^{11}} = -\beta_{11} e^{-v^{11}} \quad (16)$$

$$\frac{\partial Q^1}{\partial F^{11}} = \delta^{11} (F^{11})^{\alpha_3^1 - 1} + F_p^{11} \quad (17)$$

Then,

$$\frac{\partial \pi^1}{\partial F^{11}} = \frac{Q^1}{1 + D_1 e^{-v^{11}}} + \frac{\delta^{11} (F^{11})^{\alpha_3^1} + F^{11} F_p^{11}}{1 + D_1 e^{-v^{11}}} + \frac{Q^1 F^{11} D_1 \beta_{11}}{(1 + D_1 e^{-v^{11}})(e^{v^{11}} + D_1)} \quad (18)$$

Based on equation (18), the second derivative becomes:

$$\frac{\partial^2 \pi^1}{\partial (F^{11})^2} = \frac{\delta^{11} (F^{11})^{\alpha_3^1 - 1} + F_p^{11}}{1 + D_1 e^{-v^{11}}} + \frac{\delta^{11} \alpha_3^1 (F^{11})^{\alpha_3^1 - 1} + F_p^{11}}{1 + D_1 e^{-v^{11}}}$$

$$+ \frac{2Q^1 D_1 \beta_{11}}{(1 + D_1 e^{-v^{11}})(e^{v^{11}} + D_1)} + \frac{Q^1 F^{11} D_1 \beta_{11}^2 (D_1 - e^{v^{11}})}{(1 + D_1 e^{-v^{11}})(e^{v^{11}} + D_1)^2} \quad (19)$$

where,

$F_p^{11}$  = the remaining polynomials of  $F^{11}$  with order less than  $(\alpha_3^1 - 1)$ .

Since both  $\alpha_3^1$  and  $\beta_{11}$  should be negative due to fact that if airfare increases, the O-D demand and the market share would both decrease, therefore, the first and the third terms in the right hand side of equation (19) are negative while the second and the last terms is positive. Thus, whether the payoff function is concave with respect to airfare depends on the calibrated values of  $\alpha_3^1$  and  $\beta_{11}$ . The derivatives with respect to fare class 2 can be analyzed similarly. Meanwhile, the payoff function should be concave in most applications if the airfare is unbounded, a concavity test of the calibrated payoff function is required for the study.

### **3.3.2 Concavity of payoff functions with respect to frequency**

Because the flight frequency is an integral variable, the concavity analysis would not be performed on the basis of the derivatives. Based on equation (9), the payoff function for airline  $m$  can be written as follows:

$$\pi^m = Q^1 \times S^{m1}(v^m) \times F^{m1} + Q^2(v^m) \times S^{m2}(v^m) \times F^{m2} + (-C^m) \times v^m \quad (20)$$

Equation (20) shows that the O-D demand for the business trips, the market shares, and the costs are all functions of frequency. The first and the last terms of the right hand side of equation (20) are concave functions due to the fact that the logit model is concave and the linear model is concave, too. If the second term becomes concave, then the overall payoff function is concave because the sum of the concave functions is concave. The implication of this requirement means that the marginal revenue of the business travels decreases as the flight frequency increases.

## **4 SOLUTION APPROACH**

With the payoff function formulated in the previous section, this section presents the solution approaches for price and frequency competition under static and dynamic games.

### **4.1 Airfare competition in the static game**

Because airfare is a real variable, the price competition in static games can be written as follow:

$$\max_{F_{mk}} \pi^m(F_{mk}, F_{m'k}) \quad \forall m' \neq m, \quad \forall m, k \quad (21)$$

where,

$F_{mk}$  = the vector of air fares for the other competitors.

With the concavity of the payoff function, the following system of equations can solve equation (21):

$$\frac{\partial \pi^m(F_{mk}, F_{mk})}{\partial F_{mk}} = 0 \quad \forall m, k \quad (22)$$

In other words, the Nash equilibrium is achieved by solving the system of first order conditions in equation (22).

#### 4.2 Frequency competition in the static game

Because frequency is an integral variable, the price competition in static games can be written as follow:

$$\max_{v_m} \pi^m(v_m, v_{m'}) \quad \forall m \quad (23)$$

where,

$v_m$  = the vector of frequencies for the other competitors.

With the concavity of the payoff function, equation (23) can be solved by the following approach:

##### Step 1: Initial Real Values

Solve the following system of equations shown below and obtain the initial real values of  $\tilde{v}_1$ ,  $\tilde{v}_2$ , ..., and  $\tilde{v}_N$ .

$$\frac{\partial \pi^m(v_m, v_{m'})}{\partial v_m} = 0 \quad \forall m \quad (24)$$

##### Step 2: Compute these Frequencies by the Branch-and-Bound

Compute the values of  $v_1^*$ ,  $v_2^*$ , ..., and  $v_N^*$  by solving the system of equations shown below in ascending order.

$$\begin{aligned} v_1^* &= \arg \max_{v_1} \pi^1(v_1, \tilde{v}_2, \dots, \tilde{v}_N) \\ v_2^* &= \arg \max_{v_2} \pi^2(v_1^*, v_2, \tilde{v}_3, \dots, \tilde{v}_N) \\ &\vdots \end{aligned}$$

$$v_N^* = \arg \max_{v_N} \pi^N(v_1^*, v_2^*, \dots, v_{N-1}^*, v_N) \quad (25)$$

It should be noted that these values are integers. The solution obtained in step 2 can be viewed as a heuristic to the problem.

### 4.3 Airfare competition in the dynamic game

Assuming that the airline with the lowest marginal cost would become the market leader, and the one with the second lowest marginal cost would become the first follower, then the one with the third lowest marginal cost would become the second follower, and so on. Let the airlines from the leaders to the followers be labeled in ascending order, i.e., airline 1 is the market leader of all airlines, airline 2 follows the action of airline 1 and is followed by the other airlines, etc. Then, the simulation of the dynamic process can solve the problem for the airfare competition in dynamic games. In addition, given that the demands of the leisure trips and the business trips are separable, the airfare competition problems for these two fare classes can be solve separately.

#### Step 1: Initialization

Set the initial values of the airfares for the last  $(N-1)$  airlines to be a large number. Label these values as  $F_{2k}^{(0)}$ ,  $\dots$ ,  $F_{N-1,k}^{(0)}$ , and  $F_{Nk}^{(0)}$ . The reason for setting large initial values for the followers is that the leader may appear to be monopolistic in the beginning of the competition.

#### Step 2: Update these Airfares

Compute the value of  $F_{1k}^{(i)}$ ,  $F_{2k}^{(i)}$ ,  $\dots$ , and  $F_{Nk}^{(i)}$  for the  $i$ th iteration by solving the system of equations shown below in ascending order. This step is the simulation of reactions occurred in the dynamic process.

$$\begin{aligned} F_{1k}^{(i)} &= \arg \max_{F_{1k}} \pi^1(F_{1k}, F_{2k}^{(i-1)}, F_{3k}^{(i-1)}, \dots, F_{Nk}^{(i-1)}) \\ F_{2k}^{(i)} &= \arg \max_{F_{2k}} \pi^2(F_{1k}^{(i)}, F_{2k}, F_{3k}^{(i-1)}, \dots, F_{Nk}^{(i-1)}) \\ &\vdots \\ F_{Nk}^{(i)} &= \arg \max_{F_{Nk}} \pi^N(F_{1k}^{(i)}, F_{2k}^{(i)}, \dots, F_{N-1,k}^{(i)}, F_{Nk}) \end{aligned} \quad (26)$$

#### Step 3: The Test of Convergence

If the difference of airfares in two consecutive iterations is less than a very small value, then stop; otherwise, return to Step 2. The criteria for convergence could be set as follows:

$$\Delta F = \frac{|F_{mk}^{(i)} - F_{mk}^{(i-1)}|}{|F_{mk}^{(i)} + F_{mk}^{(i-1)}|} \leq \varepsilon \quad \forall m, k \quad (27)$$

Where  $\varepsilon$  is the tolerance level.

#### 4.4 Frequency competition in the dynamic game

Assuming that the airline with the largest market share would become the market leader, and the one with the second largest market share would become the first follower, then the one with the third largest market share would become the second follower, and so on. Let the airlines from the leaders to the followers be labeled in ascending order, i.e., airline 1 is the market leader of all airlines, airline 2 follows the action of airline 1 and is followed by the other airlines, etc. Then, the simulation of the dynamic process can solve the problem for the frequency competition in dynamic games.

##### Step 1: Initialization

Set the initial values of the frequencies for the last  $(N-1)$  airlines to be zeros. Label these values as  $v_2^{(0)}, \dots, v_{N-1}^{(0)}$ , and  $v_N^{(0)}$ . The reason for setting zero initial values for the followers is that, when the leader first enter the market, it should enjoy the benefit of monopoly.

##### Step 2: Update these Frequencies

Compute the value of  $v_1^{(i)}, v_2^{(i)}, \dots$ , and  $v_N^{(i)}$  for the  $i$ th iteration by solving the system of equations shown below in ascending order. This step is the simulation of reactions occurred in the dynamic process.

$$\begin{aligned} v_1^{(i)} &= \arg \max_{v_1} \pi^1(v_1, v_2^{(i-1)}, v_3^{(i-1)}, \dots, v_N^{(i-1)}) \\ v_2^{(i)} &= \arg \max_{v_2} \pi^2(v_1^{(i)}, v_2, v_3^{(i-1)}, \dots, v_N^{(i-1)}) \\ &\vdots \\ v_N^{(i)} &= \arg \max_{v_N} \pi^N(v_1^{(i)}, v_2^{(i)}, \dots, v_{N-1}^{(i)}, v_N) \end{aligned} \quad (28)$$

##### Step 3: The Test of Convergence

If the frequencies in two consecutive iterations are the same, i.e.,  $v_m^{(i)} = v_m^{(i-1)}, \forall m$ , then stop; otherwise, return to Step 2. In case that the equilibrium may not be found, or there are multiple equilibria in the process, the criteria for convergence should be modified as follows (Hansen, 1990):

$$\Delta v = 2 \frac{|v_m^{(i)} - v_m^{(i-1)}|}{|v_m^{(i)} + v_m^{(i-1)}|} \leq \varepsilon \quad \forall m \quad (29)$$

where  $\varepsilon$  is the tolerance level.

#### 4.5 Frequency competition in the case of alliance

Because of deregulation, currently most airlines in Taiwan suffer the decline of benefit due to the fact that more airlines had entered the domestic air travel market than ever. In order to be more competitive in the market, most of the airlines are now in alliance. The model presents in this section is a simple example of alliance.

Suppose that there are only three airlines in the market, let airline 2 and 3 be the two smaller ones. Assume that airline 2 decides to be in alliance with airline 3 such that passengers with the tickets purchased for either airline 1 or 2 can fly any of the two airlines.

If these two airlines agree that the revenue should be split according to the number of passengers being carried in their flights, and suppose that the share of the passengers is proportional to the provided frequency, then, the new payoff functions can be written as below:

$$\pi^1 = \sum_{k=1}^2 \left( Q^k \times F_{1k} \times f_{1k}(v_1) / [f_{1k}(v_1) + f_{2k}(v_2 + v_3)] \right) - C_1 \times v_1 \quad (30)$$

$$\pi^2 = \sum_{k=1}^2 \left( Q^k \times F_{2k} \times \frac{v_2}{v_2 + v_3} \times f_{2k}(v_2 + v_3) / [f_{1k}(v_1) + f_{2k}(v_2 + v_3)] \right) - C_2 \times v_2 \quad (31)$$

$$\pi^3 = \sum_{k=1}^2 \left( Q^k \times F_{3k} \times \frac{v_3}{v_2 + v_3} \times f_{2k}(v_2 + v_3) / [f_{1k}(v_1) + f_{2k}(v_2 + v_3)] \right) - C_3 \times v_3 \quad (32)$$

where,

$$f_{1k}(v_1) = \exp[V^{1k}] = \exp[\beta_{1k} F_{1k} + \beta_{2k} \ln v_1 + c_{1k}],$$

$$f_{2k}(v_2 + v_3) = \exp[\beta_{1k} F'_{2k} + \beta_{2k} \ln(v_2 + v_3) + c'_{2k}],$$

$F'_{2k}$  = the average air fare of airline 2 and 3,

$c'_{2k}$  = the joint specific constant for airline 2 and 3.

The solution approach is the same as the method described in the static games.

## 5 A CASE STUDY

The case study presented in this section is limited to the applications of frequency competition in both static and dynamic games. The analysis is based on the data acquired in the Taipei-Kaohsiung market for 5 airlines (Li, 1997). Table 1 lists the calibrated costs of these airlines based on Hansen's cost functions (1990). It should be noted that the

average costs per seat among these airlines appear to be very similar. As a result, there could be no apparent market leader in the dynamic airfare competition game.

Because of the lack of sufficient data, the O-D air travel demand model was not calibrated, instead, the following equation based on previous study of the elasticity of airfare with respect to O-D demand was applied:

$$Q_{ij} = 94451183 \cdot AF^{-1.28} \quad (33)$$

The average airfare,  $AF$ , is calculated by the weights of current market shares. Table 2 shows the calibration results of the market share model. The survey data was based on travelers' stated preferences (SP). The likelihood ratio test for the null hypothesis that the market share models in leisure and in business purposes are the same is as follows:

$$-2[\ln L_l(\beta) + \ln L_b(\beta) - \ln L_c(\beta)] = 6.4 \quad (34)$$

Where  $L_l(\beta)$ ,  $L_b(\beta)$ , and  $L_c(\beta)$  are the likelihood values for the leisure trip model, the business trip model, and the combined model, respectively.

Table 1: The cost data of Taipei-Kaohsiung airlines

Airlines	A	B	C	D	E
Cost per flight (NTD <sup>1</sup> )	130382	164855	159110	190136	170601
No. of seats per flight	130	160	155	182	165
Cost per seat (NTD)	1003	1030	1027	1045	1034

Table 2: The Estimated Parameters of the Market Share Model  
(t values in the parentheses)

Variables		Leisure	Business	Combined
Airline-specific constant	C	1.037(4.946)	1.060(6.981)	0.994(8.741)
	D	0.880(3.739)	0.906(5.452)	0.826(6.612)
Airfare (NTD)		0.00405(-7.143)	0.00255(-5.204)	-0.00317(-8.698)
Daily frequency (in natural log)		0.0404(4.551)	0.0371(4.786)	0.0397(6.969)
Ln $L(\beta)$		-334.45	-409.55	-747.2
Ln $L(0)$		-400.75	-478	-878.75
$\rho^2$		0.16	0.14	0.15
No. of sample		249	297	546

<sup>1</sup> New Taiwan Dollar, 1USD = 34 NTD.

The critical  $\chi$  square value with 4 degree of freedom and 95% confidence level is 9.49. The test statistics suggests that the differences between these two calibrated models are not significant, therefore, the combined market share model is used for further application.

Table 3 shows the solutions obtained by the application of the methods developed for static and dynamic games. It should be noted that currently most airlines are not profitable due to the fact of low ridership and high supply of airline tickets. The result of the static game with respect to frequency suggests that, with the reduction of frequency and the increase of ridership, most airlines will become profitable under current airfares. On the other hand, the result of the static game with respect to airfares shows that most airlines will enjoy larger profits if the current airfares could be even lower under current timetable. Finally, given that airline C has the largest share in the market, it has the potential to become the market leader. Suppose that airline C is indeed the leader, as a result, it will earn even more profit under the rules of the dynamic game. This result is consistent with the Stackelberg model.

Table 3: The Payoffs in Static and Dynamic Games

Airlines	A	B	C	D	E
Current daily flights	20	18	20	24	8
Current airfares (NTD)	1284	1298	1233	1220	932
Current profits (NTD/day)	-1333793	-1740695	1277588	-1176779	-1457286
Frequencies in static game	10	7	26	19	8
Resulted profits (NTD/day)	211698	290042	660902	520830	-134568
Airfares in static game (NTD)	950	900	1250	1050	1250
Resulted profits (NTD/day)	-272347	-943089	638601	-282405	250778
Frequencies in dynamic game	6	5	30 <sup>2</sup>	13	8
Resulted profits (NTD/day)	113456	234589	865432	401324	-134568

## 6 CONCLUSION

In conclusion, this paper develops a model to interpret domestic air travel market behavior. The model consists of two parts: the formulation of payoff functions, and five solution approaches to the corresponding games. The payoff functions contain the cost function, the O-D air travel demand models and the market share models for leisure and business trips. The solution approaches are derived based on the concavity analysis of the payoff functions and the means of simulation.

Finally, a case study based on Taipei-Kaohsiung air travel data is presented as model application. With the airline costs estimated by Hansen's cost functions and the market share models calibrated by travelers' SP survey data, the solutions of the static games show that current operations effectiveness may be improved if the frequency or airfares can be reduced. The result of the dynamic game also suggests that airline C, which currently has the largest market share, may earn more profit than that of the static game if airline C truly becomes a market leader.

<sup>2</sup> The market leader



Meanwhile, the model developed in the paper can also be extended to incorporate the hub-and-spoke operations in the future study. In addition, the assessment of market impact under various strategies, such as airline alliance, may also be analyzed by the inclusion of cooperative game theory for further researches.

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AIR TRANSPORT NETWORKS DEVELOPMENT

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## 1. INTRODUCTION

The high standards of living and mobility of post-war society have led to an increasing use of air transport. In the case of road, rail and air transport, this has produced an important impact on the physical landscape. These systems are almost always developed in order to meet a specific demand. Transportation studies have concerned themselves with physical layout, the origin and destination of passenger and cargo movements, and the character of transport centres, in which the essential elements are access (i.e., to activity sites) and mobility (i.e., the ability to move between them) (Hanson, 1986). Little attention was paid, however, to the development process and planning of transport geography. This process has been repeated in many places, thus creating a particular geographic pattern, leading to a general model of transport development.

The review of the literature of geographical studies of transportation usually begins with Ullman (1954, 1973), who used topology to explain spatial interaction. However, the broad outline of transport development was first demonstrated by Taaffe, Morrill and Gould (1963), who developed a descriptive generalisation of a typical sequence of transportation development, and later continued by Rimmer (1967, 1973) who adopted and improved the model in the search for spatial regularities by comparing the changes in the evolution of New Zealand and Australian seaports. The critics of transport geography, which was at the forefront of empirical quantitative geography, claim that it had become entrapped by its own narrow emphasis on network analysis and mechanistic models, and also too enamoured of the details of rational behaviour, such as minimisation of costs and distance (Knowles, 1993). This theoretical approach has not changed, despite the criticism of it as mere descriptive modelling (Sayer, 1982). Yet the critics failed to indicate which methodology ought to replace it. The quest for an explanation based upon generalisations and the search for universal empirical norms continued during the 1990s in the work of Bell and Cloke (1990). My paper attempts to dispel the notion that ideal empirical research is irreplaceable. We are setting out what Bhaskar (1975) would describe as the ideal conditions under which air transport development should occur and suggesting what we can learn from the results of this process, rather than presupposing a preconceived idea about the nature of airline operations.

Research on the development of air transport has focused to date mainly on the operating conditions of airlines, airports and government regulatory bodies, as described in the work of Gidwitz (1980), Pryke (1986), Taneja (1988), Kasper (1988) and O'Connor (1989). Many researchers have examined network development and operations in air passenger service. Pioneer work in this field began with Ferguson and Danzig (1955) and continued with the work of Miller (1963), Simpson (1966), Pollack (1974), Richardson (1976), Kanafani (1981), Morrison and Clifford (1986), Teodorovic (1988) and Shaw (1993). Various models were concerned with the optimal location of hubs in the post-deregulation period, such as the studies by Meyer and Oster (1984), Kanafani and Ghobrial (1985), and Phillips (1987). Others discussed issues such as the competition and management of passenger service at hub airports and the significance of industrial concentration, as in the work of Graham, Kaplan and Sibley (1983), Gelman and Salop (1983), Morrison and Winston (1986) and Kling, Curtis and Thomas (1991). Optimal location of hubs had a particular implication for cargo shipping, as shown by O'Kelly (1986). Non-modelling studies focused on airline economics and regulation, such as those by Meyer and Oster

(1981), Levine (1987), Kahn (1989) and Wheatcroft and Lipman (1990). The economic advantage of the hub-and-spoke network was offered by De Neufville and Gordon (1972), Devaney and Garges (1972), Chestler (1985), Spiller (1989) and Brown (1991). All these researches, however, suffered from an over-concentration on airline operation. Defining a problem and making simplistic assumptions can lead to models which may substantiate airlines operation in actual practice, but do little to explain the development process and its outcome. Therefore, in this paper we attempt to present a general theory of air transport development based on the economic and spatial characteristics of air service.

## 2. THE ECONOMIC AND SPATIAL CHARACTERISTICS OF AIR SERVICE

Air transportation is an essential part of contemporary society which touches each individual personally and as a member of society. Just as the standard of living increases in industrialised societies and the economy becomes more complex, so the means of production have an impact on the principles of availability and accessibility: the dependence on transportation becomes more pronounced. The development of an air transportation systems is a process of expanding spatial ties between points and the creation of an hierarchical system of network links. The act of air travel implies a number of independent decisions taken by individuals and organizations which are essential for the existence of an aviation transport system. The first decision is taken by individuals who want to travel, thus creating the total demand. The supply is represented by airlines who operate a fleet of aircraft servicing different routes and airports, making air traffic possible between these points. Although the airline marketplace operates primarily on economic mechanisms of supply and demand, these decisions do not suffice to sustain a system. Political considerations also constitute an essential component of the necessary set of decisions, due to the jurisdiction of each country over its land area and the air space.

Airlines have an inherent tendency toward the graduate elimination of competition, with a resultant monopoly (O'Connor, 1989). The economic rationale behind this is very simple. In a competitive situation an airline can easily enter a new market. However the presence of multiple carriers in the market might result in inefficient operations (hence losses) for most carriers. Consequently, economy-of-scale tends to eliminate small carriers who are unable to compete with large-scale entrepreneurs. Furthermore, mergers and acquisition of airlines result in an monopolistic (or oligopolistic) system. In practice, economies of scale decrease costs only up to a certain point and a monopolistic system is not likely to occur. In addition, government intervention and national prestige keep small national carriers in the market, even when they are losing money. The result is that the airline industry is traditionally treated in the professional literature as a monopolistic competitor, and this is the hypothesis followed by the Douglas and Miller (1974) theory in most studies. This assumption allows for a particular treatment of the two dominant elements: flight scheduling and level of service. For a businessman on a short business trip, a convenient flight schedule would be the most important element, whereas for a family holiday trip, a competitive airfare might be the major consideration in choosing a holiday resort. As a result, airlines usually make careful observations of the passenger composition on different flights. Reducing prices on a flight used primarily by businessmen might not be as effective as the same tactic on flights to attractive vacation resorts. Similarly, the offer of more

frequent flights with convenient arrival and/or departure times may be a more efficient way of luring businessmen.

Some may argue that airlines service is an undifferentiated product, as many passengers view the service as the same whether provided by one airline or another. This conclusion is based on the assumption that airlines operate the same type of aircraft and that passengers believe they receive the same flight amenities aboard all carriers. Although this belief may be true on some routes, the airlines have tried, and have to a large extent succeeded, in demolishing this myth. There are always passengers willing to pay more for a safer, shorter or more comfortable flight.

The development of air transport has resulted in increased competition for quality of service, which in turn has induced many companies to give passenger incentives to maintain higher load factors. Airlines also tend to over book in order to ensure high-load factors. Thus, airlines can be divided into carriers which give quality service and those that provide a no-thrill low-fare service. Air travelling is no longer the pleasure or exotic adventure of previous times. Most airports are congested places with large confusing halls and counters, and flights are tediums passengers wish would finish quickly. Airlines attempt to secure proper revenues and maintain a strong market presence by using different methods to lure in more passengers. The most common method is to cut fares. Special inducements, such as frequent-flyer programmes, can provide major carriers with a competitive advantage over new entrants with a relatively small network. Thus, passengers might not select the most competitive service (lowest fare), but rather the service that builds up the highest credit on their programme.

Air transport should be considered as a multi-attribute commodity. A number of service levels are available to a prospective traveller, all providing the same basic service, but differing in other aspects. The operation standards of airlines are of greatly differing qualities and differentiated by their scheduling operation, organisation, political factors, ownership and size. By using the spatial evolution of air service pattern we may explore the changes in these attributes, although in this paper we will focus in particular on the inter-relationship between costs, service and market share.

### 3. A MODEL OF AIR TRANSPORT DEVELOPMENT

A transport network can be said to be formed when different points in space are linked together into a uniform structure. Networks may be two-dimensional or three-dimensional. They may have either fixed channels using guided tracks or have a relative freedom of movement, as with air routes. In order to visualize air route changes a topological graph representation may be used to reduce air transport network to its simplest form, which may help to explain more clearly the developing characteristics of air transport networks. Using this method we can avoid realisation of air route corridors which Haggett (1967) characterised in the form and location of the single line. Therefore, it seems best to concentrate on two-dimensional networks with two-directional links between nodes connected to a network structure.

The topological air network in figure 1 consists of a series of points (i.e., cities or airport), which are normally linked together by air routes consisting of two-directional flights. A flight can link two cities by one-leg flight, or it can link cities through a multi-leg route which consists of a flight with intermediate stops, usually termed stopovers. Figure 1 is a partial three-dimensional graph representation of the air network. Lines which intersect and share the same crossing point do not imply the existence of a node, whose traffic may be diverted from one route to another, such as is the case in rail or road transport. Although two arcs may cross one another, they do so without intersecting, as they bypass each other in another dimension.

We have identified six phases in the sequence of air transport development (illustrated in Figure 1). In the first phase *scattered airports* service between the various airports is intermittent and disorganised. In the second phase, *penetration routes*, we see the beginning of scheduled services, although on a very limited nature, and gradually air routes begin to develop between cities. In theory, the intercity connection ought to lead to the third phase of *maximum connectivity*, in which city-pair routes are linked up to all cities. This is, however, a very inefficient phase, as a total of fifteen routes are required to link up all the cities in our six-city example. A more efficient spatial network configuration is achieved through a *fully-connected network* before this phase is fully realised. Compared with the case of maximum connectivity, only ten routes serve our six cities. Under these conditions economies of scale can be realised by using larger aircraft for connecting passengers on the interior routes, which in figure 1 includes all flights originating or terminating at airport 2. The fifth phase, *hub-and-spoke*, is allied to the growth of an efficient operating system. The efficiency of the hub-and-spoke network is clear when compared to the previous two phases. A central hub facility enables the re-routing of all flights through one central hub airport for a total of only five routes. This enables the airlines to use smaller number of large aircrafts. In the final phase, *de-hubbing*, these economies are taken one step further by the use of feeder routes and stopover flights. Since each city is linked to only one of the hubs, the spatial organization of traffic will change in one of two ways: either intercity traffic linked to the same hub will stop at the hub and then continue on to its destination; or, if the cities are linked to different hubs, then the traffic will make another stop and pass through the route connecting the two hubs, thus enabling the airlines to use even larger aircraft on the route between the hubs, which in our example connects City 2 with City 6.

The characteristics of air service in each of the six phases are different and after a thorough examination we can better understand the operating mechanism behind air transport development. Several factors affect air transport development and the demand for air services, such as fares or ticket price, flight frequency and flight amenities (i.e., seating comfort and the quality of the food served). The result is that the number of passengers on each flight may differ, and are not always related to passenger revenues. For this reason airlines are more concerned with the number of paying passengers and profit margins, rather than with the actual output (i.e., passenger-kilometres). Yet, airline output may become a significant attribute at a hub airport with restricted slots, where it may not be possible to increase an airline's level of service, as for example by adding more flights. In addition, the traffic volume and flow between cities play a major factor in the spatial location of hubs and their role in the development process. Traffic at each airport includes three types of flights: direct flights, transfers, and connecting flights. Airport are ranked by the volume and the type of flights either beginning or terminating at the airport, which

produces a hub hierarchy and spatial order of airports. The locations of the hubs move further apart as the scale effect of the inter-facility linkage increases. In such a case a lower-order system of air transport facilities and services develops in conjunction with a higher-order system.

Airlines sell more than one product and therefore the rules of classic microeconomics may not be appropriate in their case, as they often pursue yield-management objectives rather than profit maximization. Airline costs ought to have a direct effect on fares, and this is why passengers often expect operative efficiency to have a direct impact on ticket prices. However, as Feiler and Goodovitch (1994) have demonstrated, airlines commonly employ a policy of route price discrimination for various reasons, such as cross-subsidization of unprofitable routes. By so doing airlines attempt to control the number of discount fares available on each flight and restrict them to truly "capacity-controlled fares", while protecting the overall yield. This method enables the airlines to gain high revenues for their companies and sustain their market shares. "Yield management" does not necessarily attain high-profit margins however. It appears that demand for air travel in high-density markets favours yield management. Airlines in such markets often fight for prestige and a large market share and pay less attention to the effect on their operating margins. On the other hand, airlines operating in less-competitive markets employ profit management, which requires more efficient routing and scheduling design. Financially-vulnerable airlines can thus no longer afford to maintain prestigious routes and are willing to cut back their operations in order to remain viable operators. We have demonstrated three dominant characteristics of air service development: cost, service and market share, by which we try to determine the spatial development of air networks. One must examine the effect of air transport development on costs, service and market share in order to understand better the cause and effect of the model development phases.

#### 4. COSTS

Air transportation costs are commonly divided into indirect and direct costs. An airline's indirect costs are very much associated with the number of aircraft purchased, leased or operated by it. Airline start-up costs are characterized by both high "sunk costs" and significant learning-costs. A firm entering the aviation industry must be prepared for a heavy financial commitment, with the purchase of aircraft whose deliveries begin only several years after the initial payment. Once paid out, these costs cannot be fully or easily recovered by the sale of the underlying assets (GRA, 1990). In addition, the unit costs of long-established firms may be considerably lower than those of a new entrant, as the unit production costs decline as output increases. In periods of high demand, an existing carrier can collect abnormal profits. An airline's direct costs are a function of the number of routes operated, the number of passengers carried on each route (and flight leg) and the type of aircraft operated on each route. Aircraft-kilometres can be seen as an indicator of changes in airline costs and the total network costs.

The effect on costs of each of the six development phases may be analyzed by observing indirect and direct costs as a function of a) the number of aircrafts operating and b) the total aircraft kilometres. In the first two phases the demand in each market is low and any carrier entering the market may have to bear significant "learning costs". In the following

phases the demand increases to such an extent that a carrier may try to find ways to decrease total operating costs. The six city network (figure 1) is used once again to illustrate this point. In a phase of maximum connection network using linear routing between all cities, a total of thirty flight legs are required between all cities and at least fifteen aircraft are required, assuming that the distance between cities and daily frequency requires the allocation of one aircraft on each route. This phase is economically inefficient. Low load-factors can be often found on low-demand peripheral routes. The airlines "cross-subsidise" unprofitable short-haul routes either for reasons of public policy or in order to maintain feeder services from spokes to hub (e.g., to node number 2).

A central hub facility enables the re-routing of all flights through one central hub airport for a total of twelve flights, requiring only six aircraft on each route. The economic rationale of route-hubbing is simple. Passengers from a single origin and proceeding to various destinations arrive at a central hub airport, where they change flights to their final destinations, along with other passengers who also made the connection at the hub. Passengers for different destinations share a single aircraft, thus allowing larger and more cost-efficient aircraft to use the airports. The economic argument of aircraft size as explained by Bailey and Panzar (1981) maintains that larger aircraft with equal load factors have lower average costs. However, there is a limit to aircraft size and airport capacity.

The hub-and-spoke system can only benefit from cost-efficient operations of large aircraft to a certain limit. Hub airports are crowded by larger aircraft and many connecting flights. Delays, poor airport access and air traffic control problems are several consequences of this situation. Some of the traffic is moved to adjacent airport in order to ease congestion at central hub airports. Therefore, the sixth phase brings about further cost reductions in saturated markets. An efficient hub-and-spoke operation is based on perfect timing between connecting flights. Airlines attempt to overcome the "air-side" and "land-side" constraints at the hub facility by de-hubbing, and increase their load factors on low-demand routes. In figure 1 this is illustrated by the diversion of some of the traffic from the major hub airport (node number 2) to a secondary hub (at node number 6).

## 5. SERVICE

The level of service has both positive and negative effects for the airlines and their passengers. Unreliability, low frequency, poor quality or lack of capacity leads to loss of passengers to alternative operators or transport. Yet low level of service may not necessarily result in loss of passengers. A lower level of service permits higher load factors, lower average costs and, as a result, increased profits. Fewer flights allow airlines to combine passenger demand and utilise larger aircraft, thus taking advantage of economy-of-scale in order to lower average costs. Improvements in service lure more passengers and can improve the airline load factors. As demonstrated by Cole (1993), direct flights provide a much shorter journey time, and such service improvements attract a significant proportion of business and leisure travellers who are otherwise forced to take connecting flights to their destinations. Congested airports also effect the level of service in a market. Goodovitch (1991) reported that airports with a slot-constraint - such as Heathrow - affect flight frequency and capacity. As a result of the lower frequency, traffic may decline and profits decrease.



The air transport development model presented in figure 1 allows us to see the effect of network development on the level of service of the network as a whole. In the first phase service is not frequent and airline timetables change frequently between seasons and even on a monthly basis. Airlines are normally occupied with the problems of basic operations and tend to make more improvements in technology, rather than extend of routes or improve the quality of service. Phase B is the beginning of scheduled routes. The route penetration of most airlines is attained on a trail-and-error basis, in which new schedule services are added according to economic success. Service frequency is effected by problems of capital raising and limited fleet size.

When demand for travel increases, the phase of total intercity connections is reached. The goal of most airlines is market dominance and they aim to operate on all possible routes, even at the expense of low-load factors on low-demand routes. The full-development network phase is related to a regulatory environment, in which government route allocations force the airlines to operate frequent services even on economically unviable routes. Regulation has caused excessive number of flights on all routes, as service quality and frequency was perhaps the only way to compete in a regulated environment, when direct route competition was not available.

The hub-and-spoke phase is the most efficient airline network system, yet a relatively it has a poor level of service. The economic rationale behind this phase is that an increase in frequency and capacity over the whole network compensates for the effects of service flexibility, such as increased connections and longer flight time. In this phase, outbound flights from a hub airport (node number 2) bring together passengers from many origins who share the same aircraft. Each flight is scheduled such that a number of distinct routes intersect. This permits the airlines to expand the number of flights offered, or to use a more convenient flight timing. Concentration at the hub, however, influences the level of service given at the airport. Delays, congested access roads or missed connections are some of the consequences.

One solution to a low-level of service in congested hub airports is to divert some of the traffic to other airports, thus creating a multi-hub network. This occurs when the last phase of our model is reached. De-hubbing has the fewest direct flights resulting in a stopover. Flights between two cities linked to the same hub (e.g., between node 1 and node 3) will make only one stopover at the hub. If the two cities are linked to different hubs (e.g., node 1 is linked to hub at node 2 and node 5 is linked to a hub at node 6), then the number of stopovers increase and the flight must make two stopovers: one at each hub.

## 6. MARKET SHARE

Airlines defend their behaviour with their belief in the "S-curve", or the theory of prominence. The theory is that passengers in a particular market are more attracted to a dominant airline. A dominant company will naturally obtain a larger proportion of the market passenger share, as it operates more flights and offers a larger number of seats. According to this theory, airlines who want to enter a new market must increase their flight frequency, and thereby operate low-load factors in the short run, until they become a recognised force in that market. This is not to say that the only way to increase traffic is

to increase seating capacity. For if this argument holds true, airlines would be reluctant to improve the situation or develop a hub-and-spoke operation (e.g., table 2 shows that the minimum seating capacity was reached in the phase of hub-and-spoke network).

The early development of air transport - phase A - is characterised by the attempt of carriers to establish frequent service in the market. Several small carriers may co-exist with no competition or cooperation between them. The financial burdens and "learning-costs" may result in the consolidation of some airlines, but this process should be seen as financial consolidation and not as a strategic consolidation, which typifies a much later phase of the development process. When scheduled route penetration occurs in phase B, we observe an increase in the number of carriers, yet each one operates in a separate market attempting to lure passengers away from other types of travel and to promote travel as such. The maximum number of carriers in a market occurs at the phase of maximum connectivity. At this stage numerous carriers are operating on all the possible routes. As long as air transport demand is not large enough to permit frequent flights (e.g., on a daily basis), economies-of-scale are not prominent. Up to this phase, traffic increases steadily on all routes and the financial results of the airlines improve. However, when the learning economies are exhausted and regulation is relaxed, air transport quickly develops into a more efficient network configuration. Airlines resume operation of direct flights on low-density routes (e.g., from node 3 to node 4 and node 1 to node 6). At that point airlines operating from the same airport or in an adjacent market try to compete and eliminate the threat from their competitors. The number of carriers and each carrier market share is determined by the size of the market, the financial position of companies, government regulations and the available technology (e.g., aircraft type, airport capacity and new technologies).

Air transport market share is basically a function of the number of routes serving each market. The fewer the routes, the more the larger carriers will dominate the market. The most efficient route system exists in a hub-and-spoke network as presented in phase E. Such operations permit cooperation between airlines in order to reduce costs of operation or to eliminate a third competitor. Thus two airlines might agree to split revenues on a specific route which is jointly operated. One airline will fly the first leg of the route, while the other flies the second leg - the passengers making the connection through the hub airport. This process leads to concentration and congestion at hub airports, and prevents new airlines from penetrating into other markets. In the next phase, de-hubbing, the market dominance of a carrier or carriers may be broken. The effect of secondary hub (node number 6) relief of congestion at the hub (node number 2) and re-routing of some of the traffic is to allow new carriers to enter the market or to increase their competitive threat and market share.

## 7. A NUMERICAL EXAMPLE

We used a numerical example to demonstrate the effect of air transport development on costs, service and market share in order to show the cause and effect of the model development phases. In the following numerical example we assume the given model of air transport development as shown in figure 1. The distances between the airports of the six cities are equal (2,000km) and one aircraft can serve each city-pair market with one round-trip flight a day. The daily passenger demand at each market is presented in table 1. In the following numerical example we present the changes in costs, level of service and market share for each developing phase. Total costs are a function of the number and type of aircraft, the number of routes and flights, and the average network load factor (the ratio of passengers to available seats) on each route. Level of service is a function of market flight frequency, seating capacity and passengers-kilometres. We have calculated the average origin destination (O-D) seat availability for all zones (airports). The market share indicates the carriers market dominance. The total number of routes is a measure of possible route competition, in which the ratio between the zone with the minimum number of routes and the zone with the maximum number of routes determines the possible level of competition in the market.

In the first two phases, *scattered airports and penetrating routes*, the demand for air travel is unexploited (hidden demand). Thus, some potential customers do not know of this possibility and others may not yet realise the advantages of flying. The airlines are also experimenting with the market potential. Costs, level of service and market share are consequently not stable and the industry in this region experiences a period of early growth. By the time we reach the phase of *maximum connectivity*, the market demand as presented by table 1 can be fully realised.

The third phase, *maximum connectivity*, is characterised by relatively high costs and service as the number of aircraft serving the market is at its peak and direct flight makes passenger-kilometres the lowest. Market share is at its peak, since an equal number of flights are serving each market and no advantages to scale can yet be achieved. Once we have moved to a more economically-efficient network development phase, these results change significantly. In table 2 we have summarised the results of the above numerical example. The fourth phase, *fully connected network*, allows cost-saving operation by a 33% reduction in the number of routes and aircraft-kilometres. This allows for higher load factors, but the service deteriorates and competition forces some of the smaller carriers out of the market. Passengers are forced to fly longer distances and have fewer direct flights. But, higher level of service (seating availability) can compensate by more frequent service, although this is usually not the case, since the airlines will tend to use larger and more efficient aircrafts. For this reason we see that total number of aircraft has been reduced from fifteen to ten planes only between phase C and D.

Maximum concentration is achieved in a hub-and-spoke system. In this phase the airline can benefit from the lowest costs as aircraft-kilometres are reduced by 50%. Load factors and seat availability increased, but the average available seating capacity in each market is lower, and passengers suffer from lower probabilities to find available seat on a desired flight. Passengers are also expected to experience lower level of service and longer hours on board. Very few direct flights exist and all of them to the hub airport. This phase can assist

most major airlines to take advantage from the economies-of-scale at the hub. Yet this can also work against the carrier. Congestion, denied boarding and delays at the hub may facilitate the process of de-hubbing. In this phase passengers may suffer from even longer flights with up to two connections, but are compensated by better seat availability. Market share also can change if competitors may decide to enter the market and obtain control over the secondary hub.

## 8. CONCLUSIONS

A major characteristic which distinguishes the air transport market from other economic activities is the use of spatial networks both as a means of supplying services and a strategic instrument for cost reduction. It is also a competitive mechanism with the goal of deterring or encouraging new airlines from entering the market. Airlines have an inherent tendency toward the elimination of competitors, with a resultant monopoly and more cost-efficient network configuration. Most airlines ought to be concerned with the effect of service on the demand for travel, as unreliability, low frequency, poor quality or lack of capacity lead to a loss of passengers. Similarly, service improvements lead to higher load factors and passenger numbers. In order to explain the conditions under which air transport has developed, we have identified six phases in the sequence of network development and examined subsequent changes in costs, service and market share for each one. In the first phase, *scattered airports*, service between the various airports is intermittent and air service disorganised. In the second phase, *penetration routes*, we see the beginning of scheduled service, although on a very limited nature, and air routes begin to develop between cities. Theoretically the intercity connection leads to a phase of *maximum connectivity*, in which city-pair routes are linked to all cities. This is a very inefficient phase however, as a total of fifteen routes are required to link up between all cities in our six city example. Usually before this phase is fully realised, a more efficient spatial network configuration is brought about through a *fully-connected network*. Only ten routes serve our six cities compared with the case of maximum connectivity.

The fifth phase, *hub-and-spoke*, goes hand-in-hand with the growth of an efficient operative system. The efficiency of the hub-and-spoke network is obvious when compared to the previous two phases. A central hub facility enables the re-routing all flights through one central hub airport for a total of six routes only. An airline can make significant cost savings, compared to direct-flight operations, improve load factors and attain a higher level of service. Consumers can benefit from more frequent service during off-peak hours and from lower fares resulting from reduced operation costs for the airline. In the last phase, *de-Hubbing*, these economies are taken one step further using feeder routes and stopover flights to reduce the number of aircraft necessary to link up all cities and reduce total block hours. As each city is linked to only one of the hubs, the spatial organization of traffic will develop in one of two ways: either traffic between cities linked to the same hub will stop at the hub and then keep on to its destination; or, if the cities are linked to different hubs then the traffic must make another stop and pass through the route connecting the two hubs together.

This paper has discussed the dynamics of air transport and examined the driving mechanism behind this process. Rather than presupposing an abstract theory about airlines operation, we have presented a general theory of air transport development based on the economic and spatial characteristics of air service. We believe that an understanding of the spatial behaviour of airlines will contribute to better airport planning, government regulation and airline management in the future.

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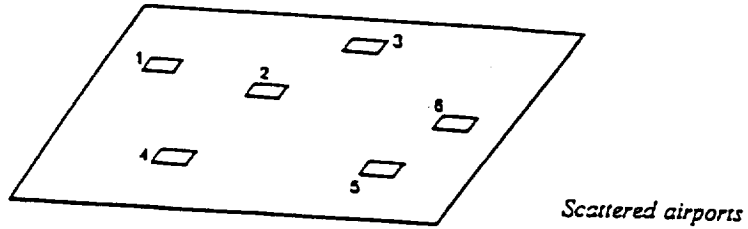
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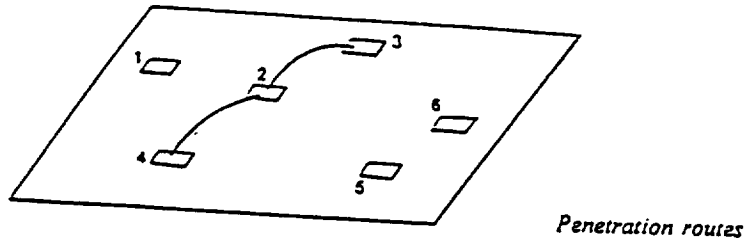


FIGURE 1: A MODEL OF AIR TRANSPORT DEVELOPMENT

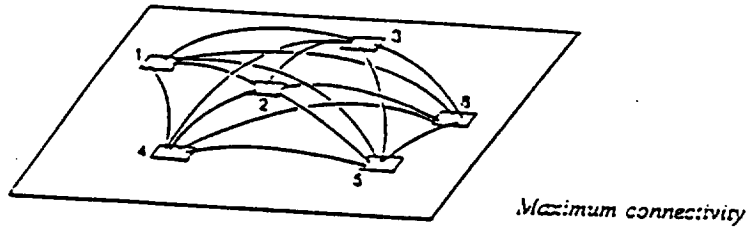
Phase A: sporadic service is available between scattered airports.



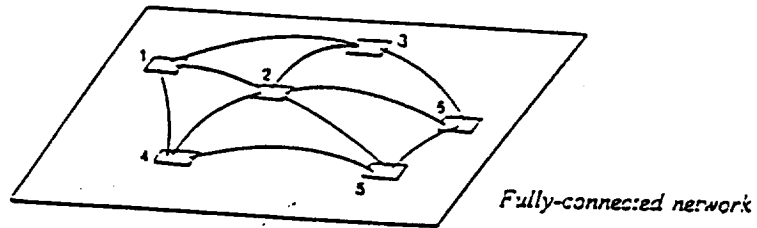
Phase B: scheduled routes open between the cities.



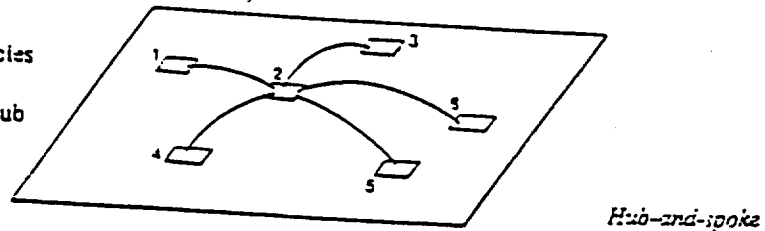
Phase C: the phase of complete intercity connections is reached.



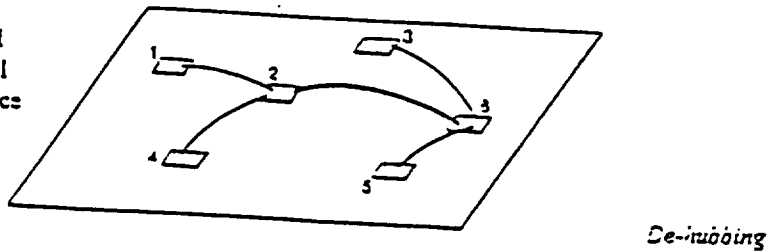
Phase D: a more efficient spatial network configuration is achieved.



Phase E: a central hub facility enables a more efficient operations by the re-routing all flights through one hub airport.



Phase F: the number of flights and flights times required to link-up all cities is reduced using feeder service and stopover flights.



## FIGURE 1: A MODEL OF AIR TRANSPORT DEVELOPMENT

Phase A: sporadic service is available between scattered airports.

*Scattered airports*

Phase B: scheduled routes open between the cities.

*Penetration routes*

Phase C: the phase of complete intercity connections is reached.

*Maximum connectivity*

Phase D: a more efficient spatial network configuration is achieved.

*Fully-connected network*

Phase E: a central hub facility enables a more efficient operations by the re-routing all flights through one hub airport.

*Hub-and-spoke*

Phase F: the number of flights and flights times required to link-up all cities is reduced using feeder service and stopover flights.

Table 1: City-pair demand matrix

Zon e	1	2	3	4	5	6	Su m
1		25	25	25	25	25	125
2	25		25	25	25	25	125
3	25	25		25	25	25	125
4	25	25	25		25	25	125
5	25	25	25	25		25	125
6	25	25	25	25	25		125
Su m	125	125	125	125	125	125	750

Table 2: Air service characteristics

	Number of Routes	Size of Aircrafts	Total . Aircraft Km	Total Passenger Km	Average Load Factor	Average O-D seat availability
Phase A: Scattered Airports	1	0	2,000	varies	varies	varies
Phase B: Penetration Routes	2	2: 50seats	4,000	varies	varies	varies
Phase C: Maximum Connectivity	15	15:50seats	60,000	1,500,000	50.0%	50.0
Phase D: Fully Connected Network	10	5: 50seats 5: 100seats	40,000	2,000,000	66.0%	33.0
Phase E: Hub-and-Spoke	5	5: 150seats	20,000	2,500,000	83.0%	75.0
Phase F: De-Hubbing	5	4: 150seats 1: 400seats	20,000	2,900,000	72.5%	183.3



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# **Performance Evaluation of Carriers by North American Companies**

by

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# PERFORMANCE EVALUATION OF CARRIERS BY NORTH AMERICAN COMPANIES

## Abstract

According to the trade press, performance evaluation in North America is well underway. This paper reports the findings of a research study to examine the assessment of carrier performance by users and suppliers of North American transportation services. As a descriptive study, it examines the approaches of cargo suppliers (manufacturers) to the evaluation of their transport suppliers' performance—incidence of monitoring, methods, responsibility for and use of findings—in order to understand the business practices taking place. These findings are then contrasted with similar elements from the points of view of carriers and logistics service firms. The paper does not explore the issue of performance assessment from a macro-economic focus but rather from one of firm-specific program implementation. It concludes that the perception advanced by the trade press is not the reality reported by companies in the marketplace.

## Introduction

Performance evaluation in the North American transport system is well established according to the trade press. This paper reports on the findings of a research program to examine the assessment of carrier performance by buyers and suppliers of North American transportation services.

Specifically, the research program examined the approaches of cargo suppliers (manufacturers) to the evaluation of their transport suppliers' performance, in order to understand the business practices taking place. The survey of manufacturers, undertaken in 1995 and reported in Brooks (1998), found very few differences between Canadian and American companies. It also uncovered few differences between firms shipping high value goods and those shipping low value goods. However, there were significant differences between companies operating according to Just-in-Time (JIT) requirements and non-JIT companies in their use of quality programs and of formal carrier performance monitoring. Many of the carrier performance measurement systems used by manufacturers did not appear to be that well established scientifically, and remained the purview of large companies.

Subsequently carriers and logistics service firms were surveyed, in 1996 and 1997 respectively. These results are being reported in two articles (Brooks, forthcoming a and b). The results of the carrier survey were not similar to those of the manufacturers. Carrier participation in systems monitoring their own performance was high and the size of firms undertaking performance evaluation was quite diverse. The reliance of carriers on customer surveys involving

subjective evaluation and measuring customer satisfaction was particularly interesting. The limited use of objective metrics measuring operating performance was not expected.

The survey of logistics service companies (LSCs) provided the opportunity to explore differences in carrier performance monitoring practices between those LSCs that own transport assets, and therefore might presumably behave more like carriers, and those that provide pure services and therefore are more like cargo suppliers (manufacturers). This segment of the study had serious non-response problems with a high number of surveys returned as undeliverable, and a serious lack of interest on the part of U.S. firms. Descriptively those practices will be included here.

This paper reviews the findings of the research program with respect to those parties with a formal carrier monitoring program in place, contrasting buyer findings with similar elements from the point of view of carriers and logistics service firms from a program implementation viewpoint.

## **Literature Review**

In the last decade, the market for transport services has changed dramatically. Deregulation, time-based competition and the resultant focus by many buyers on JIT strategies have resulted in new buyer-seller (shipper-carrier) relationships for many companies in the transport industry. This trend is reinforced by the implementation of global production and distribution systems by many transport buyers and contractual relationships (including strategic alliances) have become more common. The move away from price-oriented transaction-specific carrier selection and towards alliances and negotiated transport service contracts has been reported by a number of authors (Brooks, 1995; Gibson *et al.*, 1993; Crum and Allen, 1991; Kleinsorge *et al.*, 1991). Lieb and Millen (1988, 1990) noted that JIT implementation leads to both a change in criteria by which carriers are selected and the number of carriers used. This research program was developed as it became evident during the course of the research done by Brooks (1995) that two trends had challenged the traditional transaction-based approach: (1) carrier-shipper contractual alliances accounted for a substantial share of the total volume of transport purchase transactions and (2) the role of logistics service firms was larger as outsourcing of logistics activities became more frequent.

The criteria by which shippers choose carriers have been studied for the past three decades and these studies were briefly reviewed in Brooks (1998). Most of these studies suffered from the failure to link carrier selection attributes to the shipper's perception or assessment of the performance of the carrier and whether or not that performance differentiated carriers on a particular service dimension. In other words, the research failed to incorporate Aaker and Day's



(1980) classic model of purchase behaviour. According to the Aaker and Day (1980) model, a carrier must be seen as having the attributes deemed by the buyer to be important to the buyer and be perceived to perform better than other carriers on those attributes, e.g., the carrier alternatives must be viewed to be different. The existence of well-defined performance evaluation systems enables the buyer to assess the difference he or she is purchasing and its relative value, evaluate the transport supplier in terms of meeting or exceeding expectations and assist the buyer in establishing service targets for future purchases. The existence of well-defined performance evaluation systems enables the seller to assess relative performance in areas of importance to customers against industry benchmarks, previous performance, competitor performance and/or future service targets; identify areas for continuous or innovative improvement initiatives; take greater control of areas of logistics or strategic importance to the company; and more.

There have been articles on performance measurement from the perspective of the purchasing manager, often drawing conclusions about the types and effectiveness of those systems in place (e.g., Dumond, 1991). However, this work has generally not focused specifically on the purchase of transport services. What better way to change the perception of performance than to have documented operating evidence of performance differences? The desire to investigate the processes of carrier performance monitoring and accompanying performance measures (or metrics) arises from the urge to improve the results of the transport supply purchasing decision.

Although there is the context of supply chain management and broader supplier selection issues in which to place this research, the larger context is not reviewed here. According to both the trade and academic press, supply chain management and logistics management are coming of age in U.S. firms. Logistics management is also well established in Europe (Bardi and Tracey, 1991; Randall, 1991); however, it remains unclear as to how widely adopted it has been in Canada as Canadian literature in this field is very thin. There is also a growing body of literature in the logistics performance field. This literature is reviewed by Chow *et al.*, (1994) and their review shows a significant gap in the development of hard measures of performance although they do note the excellent work by the NEVEM Working Group (1989) on developing processes for defining metrics such as order fill ratios, order cycle times and the like to measure performance. Little research has examined the actual incidence of and practice of transport performance monitoring activity. It is the author's view that carrier performance evaluation is one tool used by supply chain or logistics managers to acquire, secure or maintain competitive advantage and that these management fields are much larger in scope than that of transport performance evaluation. Fawcett and Clinton (1996) accord performance measurement a very small but vital role in their model of logistics strategy implementation.

The urgency for research into transport performance monitoring is driven in some measure by the trend towards carrier reduction strategies on the part of manufacturers. Byrne and Markham (1991) reported a 1989 A.T. Kearney survey of 2000 U.S. manufacturing companies, documenting the trend towards manufacturer consolidation of supplier bases and resultant focus on building closer ties with those they retain. This holds for input suppliers as well as logistics and transport suppliers. The development of specific metrics to be established as benchmarks appears to be, if the majority of trade press articles are believed, an in-house activity or one which is purchased from suppliers of a performance monitoring service. Part of the purpose of the research program reported here is to better understand the state of the art of carrier performance monitoring.

From 1990 to 1995, the Intermodal Association of North America (IANA) completed five studies of carrier performance evaluation practices in the U.S. These studies, conducted by Mercer Management, are the most important of the industry association studies, both in terms of coverage and continuity. The IANA (1995) study concluded that while two-thirds of shippers have Total Quality Management processes established, only one-third have a formal performance measurement, or "report card," system in place for the evaluation of their transport suppliers. When viewed on an industry-by-industry basis, the chemical industry was the leader in the use of report cards, perhaps because of the public risk implied in performance failure, or perhaps because the chemical industry has promoted the "Responsible Care Initiative." (This is a standard that stipulates procedures for environmental protection.) The IANA studies only examined monitoring practices by U.S. manufacturers, leaving out the two other players that may also undertake carrier performance monitoring—the carriers themselves and LSCs.

According to LaLonde and Maltz (1992), logistics is among the most commonly outsourced business support services. The pattern of third party usage is expected to continue in the future, although Aertsen (1993) and Rao *et al.* (1993) identified a number of reasons companies do not contract out distribution, and Stank and Daugherty (1997) found that when manufacturers face few dominant logistics suppliers, they are less likely to form co-operative agreements, not wishing to become dependent on dominant firms. A discussion of carrier performance cannot be complete without the views of all in the buyer-seller relationship, including third party purchasers.

But what is the "performance" that North American companies currently measure? A.T. Kearney (1985) defines performance as the ratio of actual output to a defined standard output. This standard may be an industry benchmark or a company defined goal. It has been argued that customer satisfaction is the important measure of performance, and that it is a product of both performance metrics that meet or exceed expectations and the communication of such

performance metrics to the decision-maker. Mentzer and Konrad (1991, p. 33) observe that "performance measurement is an analysis of both effectiveness and efficiency in accomplishing a given task." Rhea and Shrock (1987) note that meaningful assessment of distribution effectiveness encompasses more than evaluating customer satisfaction. Therefore, a comprehensive assessment of distribution performance includes both an external evaluation of effectiveness (meeting or exceeding customer expectations) and an internal appraisal of efficiency (resource utilization) in order to achieve long-run profitability. This efficiency/effectiveness paradigm, explained by Mentzer and Konrad (1991), balances the relationship between buyer and seller while providing the seller of the service with guidelines for the establishment of service delivery targets and focus for the necessary continuous service improvement. A rational review of superior service delivery should, but may not, result in a satisfied customer. Likewise, the existence of acceptable (to the carrier) customer satisfaction surveys should not serve as an excuse for failing to evaluate operating performance.

This paper identifies the incidence of performance evaluation on the part of the buyers and sellers of transport supply as well as reports on views held of the activity and the performance measures in use within the transport market.

## **Methodology**

In the overall research program, three groups—buyers, carriers and logistics service firms—were contacted in two countries, Canada and the U.S.A. The first article (Brooks, 1998) focused on a survey sample of 960 buyers (of which 5 were duplicate companies) in the summer of 1994, while the second (Brooks, forthcoming a) reported the results of a survey of 455 firms in each of two transport supplier groups: Canadian carriers (215) and U.S. carriers (240). This second survey was conducted in the fall of 1995. The target of 240 Canadian carriers was not met because there were not sufficient unrelated firms found. The third survey, reported in Brooks (forthcoming b), is of 480 firms in two other supplier groups: Canadian LSCs and U.S. LSCs. This third survey was conducted in the fall and winter of 1996-97. All surveys were mailed questionnaires. The original sample parameters were chosen to compare buyers (manufacturers) with sellers (carriers and LSCs) with some emphasis placed on comparing the sub-groups of sellers to determine if LSCs more closely resembled buyers than sellers.

The findings reported here contrast the findings of the three different surveys and are largely descriptive—defining the incidence of and practices in carrier performance monitoring. The response results are shown in Table 1.

**Table 1: Response Experience**

	Manufacturers	Carriers (1)	LSCs
Questionnaires Mailed (2)	955	455	480
Usable Questionnaires Returned	116	93	77
Canadian	74	55	60
U.S.	42	38	17
Questionnaires Returned but Deleted From Analysis (3)	0	4	2
Other Returns (4)	136	66	140
Replied, Refusing to Participate (5)	173	49	42
Non-respondents	530	243	219

- Notes: (1) There were insufficient Canadian carriers unrelated in order to achieve the quota sample of 240. (Continued random sampling only yielded duplicate records, e.g., another branch office of the same company.) Only 215 Canadian companies were contacted.
- (2) The target of 960 users contained 5 duplicate companies and the sample was not supplemented.
- (3) These were deleted as a review of the responses proved they were inappropriate companies.
- (4) Address unknown, moved with expired forwarding order or no longer active as a business.
- (5) A number of companies refused because of company policy, the nature of their business, insufficient volume to be interested, or they did not believe the study was relevant to their business. Some complained about too many surveys.

The response rate for U.S. LSC firms was particularly disappointing. The number of unavailable participants due to delivery failure was discouraging. Attempted follow-up of these through directory assistance, searching 14 other directories and on-line searches confirmed the suspected high failure rate of this type of business. The potential for non-response bias—the inaccuracies that arise from failure to obtain information from a sizable portion of sample members—is certainly present as only 17 U.S. firms chose to participate in the study. Two of three causes of non-response bias are clearly evident: refusal to respond (choosing not to participate) and inaccessibility to the researcher (the target respondent had moved with an expired forwarding order and the telephone was disconnected; in other words, untraceable). The reasons for the disappearance of a substantial number of directory listed firms is a matter for speculation.

That said, it was intended that a number of research hypotheses would be tested and the Canadian and U.S. respondents compared; however, the U.S. LSC subset is too small and it would be foolish to draw any definitive conclusions about the differences between Canadian and U.S. firms. The findings reported here are therefore descriptive, with quantitative evaluation only where non-response bias is not an issue.

**Table 2: Size of Firms Monitoring (1)**

Type	Under \$25M Sales	Over \$25M Sales	Non-Responses (2)	Monitoring (% of total)
Manufacturers	7	45	4	56 (48%)
Carriers	21	56	3	80 (86%)
LSCs	17	18	2	37 (48%)
All	52	125	9	173

Note: (1) These firms indicated they had a formal monitoring program.  
(2) On this question of size in particular.

Perhaps most interesting is the reporting of formal carrier performance monitoring by company size and how that differs between users and carriers (Table 2). In the study of users (Brooks, 1998), it was clear that formal monitoring was more likely to be undertaken by large rather than small companies. In that study, none of the companies reporting sales of under \$5 million conducted formal monitoring of carrier performance; only seven users with sales under \$25 million undertook any type of formal performance monitoring with inspection as the prime method. On the other hand, even small carrier companies participated in formal monitoring (Brooks, forthcoming a). A review of these small carrier companies showed 81% had in-house performance evaluation programs with 43% conducting spot monitoring. The widespread use of performance evaluation in support of improvement in operations was noteworthy. As for the LSCs, there appears to be a greater participation in carrier performance monitoring by smaller firms. This may be due to survey timing, as the LSCs were surveyed two years later than the manufacturers, or it may be because the case for performance evaluation is becoming more compelling as greater competitive pressures force smaller firms to undertake this type of assessment.

## **Findings—Performance Evaluation Practices**

### ***Incidence of and responsibility for performance monitoring***

As already noted in Table 2, not all of those contacted during the three surveys engaged in carrier performance monitoring. As can be seen in Table 3, the practice of performance monitoring varied significantly between the types of respondents. The need for or desirability of carrier performance monitoring is apparently not as evident to manufacturers and LSCs; less than half of these companies monitor performance. The reasons for this view are captured in the following quotes from two logistics service firms not supporting purchaser monitoring:

There is no need for 'formal' make-work monitoring; either the service is there or it is not.

If your carriers meet your price and delivery requirements, they keep your business; if not, they lose. Why spend time, money and resources on formal monitoring? We have real work to do, our business to focus on.

On the other hand, 86% of the carriers responding monitor their own performance.

**Table 3: Monitoring Activity**

Type of Company	Total Number of Companies	With Formal Monitoring	With Report Cards (% of previous column)
Manufacturers	116	56	17 (30%)
Carriers	93	80	35 (44%)
LSCs	77	37	20 (54%)
All	286	173	72 (42%)

Of the companies that monitor carrier performance, virtually all (93%) of the carriers supported the notion that transport carriers should formally monitor their own performance independent of whether their customers request such monitoring. As well, a substantial percentage (38%) of these carriers also believed monitoring should be done by the purchaser of the transport services. Some carriers expressed the view that carriers benefit from performance monitoring through continuous improvement, and one observed that "all service suppliers should be confident enough to publish their standards, allowing competitors and customers to monitor service success." That opinion should support the development by carriers of report cards, to an even greater extent than the 44% represented in Table 3.

The use of report cards among manufacturers is no greater than that found in the IANA studies but 16% of the 116 manufacturers were of the opinion that responsibility for the provision of report cards lies with carriers. LSCs were greater supporters of report cards than were the manufacturers in this survey.

In the subsections of this article beyond this one, the only data discussed will be that from companies currently engaged in carrier performance monitoring and not that of all respondents, as these findings already have been discussed in Brooks (1998, forthcoming a and b).

### **Methods**

When monitoring is a desired company activity, what can be said about the methods used? Given the picture painted in Table 4, more than one method of evaluation is perceived as useful for evaluating carrier performance by all parties answering the surveys.

The methods used for formal monitoring by users were requested and audits, inspections and process reviews surfaced as the overwhelming choices. Certification and testing were not favored by users as means of monitoring performance, with less than 15% of companies using these techniques. A number of manufacturers supplied other performance evaluation practices that they specifically undertake including sales call reports and surveys of their customers to determine satisfaction with carrier performance.

**Table 4: Performance Review Methods**

Methods (1) Used By	Manufacturers	Carriers	LSCs
Audits	64%	14%	11%
Process Reviews	55%	55%	49%
Customer Complaint Levels	NA	58%	51%
Service Performance	NA	91%	84%
Other	59%	20%	24%
n= (2)	56	80	37

Note: (1) The question was worded differently for users, as they were presented a wider range of options. Inspections were used by 52%; certification by 12%; and testing by 9%. Service performance and customer complaints were not offered choices but written in by respondents. For manufacturers, other often included monitoring the temperature in refrigerated containers (34%) as a method of evaluating the suppliers' ability to meet terms and conditions of hire in this special market.  
 (2) Respondents were allowed to check as many as applied.

One manufacturer believed that good performance can only be confirmed by audit because

I have seen transportation of food items on the same truck with pesticides. The only way to be sure is by doing an audit.

In spite of manufacturers reporting that audits were used to monitor performance, many carriers did not believe that their customers used third party audits to monitor performance. Only 9 of the 117 carriers and LSCs with formal monitoring programs were of the opinion that performance evaluation should be conducted by a third party audit, either at the customer's or carrier's discretion. The derogation of third party audit is surprising as it is a readily contracted and accessible service, even for the smallest firm. Of the 173 firms with formal monitoring programs, 70% have developed their own in-house program. Many carriers were open to developing a custom solution for the customer demanding specific information. Other suggestions included the use of ISO 9000 and 9002.

The 80 carrier firms that used a formal program to evaluate transport performance were asked to report the method(s) employed to evaluate such performance. The majority of respondents indicated the use of service performance measurement. Customer complaint levels

were used for evaluating performance by 58% while process review was the third most popular method of evaluation, with 55% of respondents using this method. Alternative methods of performance evaluation, such as analyzing claims ratios or sales growth, satellite tracking, customer surveys, and so on, were suggested by 20% of firms.

When questioned about the type of formal program to evaluate its own performance, 78% of the carriers with formal monitoring programs have developed their own in-house program. Contracted third party audits were seldom used, while spot monitoring and customer programs were each used by one-third of respondents. Other suggestions included service failure reports (completed by the sales department), satellite tracking and customer service surveys.

Of the 37 logistics service suppliers formally monitoring carrier performance, 84% of firms indicated that they measured service performance. Process reviews were used by 49%, while 51% used customer complaint levels. A very low percentage of both Canadian and American firms used third-party audits (11%) to evaluate transport performance. The preference patterns of Canadian and American firms were similar but non-response bias prevents the formation of a definite conclusion.

**Table 5: Performance Report Use**

Use Of the Report	Manufacturers	Carriers	LSCs
For Formal Review Session	38%	53%	54%
For General Discussion of Service	38%	44%	49%
For Negotiation on Service Elements	32%	25%	46%
As Part of the Sales Approach	NA (1)	54%	49%
For Measuring Process Improvement	NA (1)	56%	52%
To Document Bonuses, Penalties or Service Guarantees	NA (1)	25%	38%
Other	NA (1)	54%	51%
n= (2)	56	80	37

Note: (1) The question was worded differently for users, as they were presented a narrower range of options. Justification for carrier removal was only asked of manufacturers and accounted for 36% of those who monitored.

(2) Respondents were allowed to check as many as applied.

***How should performance reports be used?***

The use made of performance reviews by transport buyers is a central issue in the implementation of a successful performance evaluation system. Where in the process is feedback



used? There was user agreement (Table 5) that carrier performance documentation should be used for formal performance reviews, to assist in carrier selection, as general input to service discussions, as justification for removal of a carrier from use by the company and as input to negotiations over the service provided. A small number of companies also suggested that evaluations should be used for commendation or recognition of excellent service providers and for reward through rate increases.

Carriers used the system as a method of evaluating and/or measuring process improvement, as part of a sales strategy to clients or to provide a formal feedback mechanism. It was seen less as a tool for general discussion or negotiation or to document bonuses, penalties, service-related guarantees. For LSCs the pattern was also one of a multi-use tool.

***How often should report cards be shared?***

The question posed to the carrier and LSC survey participants with report card programs was "how often should your performance report card be reviewed with your customers?" The most frequent response from carriers was customer-focused—as often as the customer warrants because it depends on the customer. (See Table 6.) LSCs agreed but not as strongly. Of those favouring periodic reviews, quarterly reviews were preferred by manufacturers and carriers with monthly reviews the choice of LSCs. There was some favour of annual reviews shown by manufacturers but not by LSCs. Practice appears to vary widely and there is little consensus on what is an appropriate time-frame for conducting periodic regular reviews.

***Table 6: Report Card Review Timing Preferences***

Frequency with which report card should be reviewed(1)	Manufr. should review carrier performance with carriers	Carrier should review its performance with customers	LSCs should review carrier performance with carriers
As often as the customer warrants	NA	54%	25%
Monthly	12%	20%	40%
Quarterly	53%	40%	10%
Annually	24%	3%	0%
Other (2)	18%	6%	5%
n= (3)	17	35	20

Note: (1) Totals do not equal 100% as respondents were allowed to check more than one.  
 (2) Other included different timing alternatives. NA = Not asked.  
 (3) Respondents were able to check more than one. Only those with report cards are reported here.

Carriers and LSCs with report cards were asked how frequently users seek to review their performance (Table 7). Among those with report cards, reviews are sought by transport

buyers periodically, when there is a problem with performance or when sales staff are meeting the customer. There was little consensus on what is an appropriate time-frame for buyers to seek reviews of performance. Interestingly, LSCs reported that reviews are sought by transport buyers annually; this is an interval not recommended by LSCs as noted in Table 6. None of the LSCs with report cards reported reviews sought by transport buyers when sales staff are meeting with the customer.

### Quality program activities and perceptions

It is important not to conclude that the existence of a quality program implies that monitoring of transport supplier performance takes place. The underlying assumption that transport supplier performance evaluation, just-in-time processes and quality programs would go hand in hand was supported in the pilot testing for the research program but was not supported in survey of users. The research found there are manufacturers engaged in quality programs that do not evaluate transport supplier performance just as there are manufacturers that operate just-in-time processes but do not monitor transport performance. Of all the companies surveyed in this research program, only 5 in 12 manufacturers, 5 in 10 carriers and 5 in 9 LSCs reported participation in transport supplier monitoring programs. Quality program participation by only those companies that monitor carrier performance is reported in Table 8.

**Table 7: Performance Review Timing Sought by Customers**

Frequency with which customers seek to review our performance	Carriers	LSCs
When there is a problem	23%	15%
When there is a sales meeting	26%	0%
Monthly	31%	40%
Quarterly	26%	35%
Annually	17%	25%
Other (1)	14%	5%
n= (2)	35	20

Note: (1) Other included different timing alternatives. NA = Not asked.  
 (2) Respondents were able to check more than one. Only those with report cards to share.

But is ISO 9000 certification a requirement for doing business? Of the 173 companies, 27% were ISO 9000 certified. None of the manufacturers required mandatory participation in ISO 9000 for their transport suppliers although one-third suggested that their transport suppliers be registered. None of the carriers responded that all its customers required participation in such

programs, while only 13% indicated that more than 50% of their customers require quality programs. The pattern was similar for LSCs.

ISO 9000 is only one of many quality programs. The study found that the Malcolm Baldrige Quality Award (MBQA) program appears more frequently in the trade press than in business practice (Table 8). In conclusion, in-house quality programs and ISO series programs were more popular than other methods of documenting processes.

### Findings—Performance Measures

In spite of what the trade press would have readers believe about the advanced state of performance measurement and the sophistication of such measurement, performance measurement systems do not appear to be as well-entrenched scientifically as hoped. Report cards provided by all parties illustrated the continuing reliance by many firms on subjective data. The number of firms employing quantifiable objective metrics, such as deviation in minutes, hours or days from delivery time, percentage of equipment rejected, error rate in billings or number of customer complaints received, was fewer than anticipated at the beginning of the research program. In all, 30 manufacturers, 7 carriers and 2 LSCs provided either detailed listings of their report card contents or the report cards themselves. The average number of variables tracked by these users was diverse and company-specific. There were no commonalities of style or type among those received, with the exception that more were subjective than objective in format.

**Table 8: Quality Program Participation by Monitoring Companies**

Program Participation Rate	Manufacturers	Carriers (1)	LSCs (2)
Do Not Participate	65%	38%	65%
Participated but Discontinued	12%	4%	3%
Currently Participate in (3)	23%	58%	32%
In-house Program	100%	63%	50%
ISO 9000 Series	100%	46%	58%
Baldrige/CABE	0%	13%	21%
Other (1, 2, 4)	12%	22%	13%
n= (5)	52	80	37

- Note:
- (1) Other quality systems are used but not in substantial numbers: contracted third party audits by 6%, customer or industry association designed programs by another 8%, and other programs, such as TQM, Philip S. Crosby Quality College, statewide quality awards, and so on, by 12%. Some carriers had more than one quality program in place.
  - (2) Other quality systems are used but not in substantial numbers: contracted third-party audits by 3%, customer or industry association designed programs by another 8% and other programs by 11%.
  - (3) Respondents were allowed to check as many as applied. Some had more than one quality program in place.
  - (4) Other systems were third party audits.

- (5) Only those which have a monitoring program are included here. Only 52 of the 56 manufacturers answered this question.

What is measured by users? More than anything else, on-time pick-up and delivery was the most collected performance metric used by manufacturers. This was quite consistent with the views of LSCs (Table 9). Surprising was the clear divergence between the monitoring of pick-up and delivery times by manufacturers and LSCs on the one hand and carriers on the other. Damage claims or incidence of damage, billing accuracy, the correct equipment/condition of the equipment were all frequently mentioned.

As can be seen from Table 9, a wide range of metrics are used to measure performance. In addition to those common elements identified in Table 9, all parties had particular other service points that should be included in an effective monitoring system (and these are mentioned in the footnotes to Table 9).

**Table 9: Most Commonly Identified Service Elements for Monitoring**

Service Element	Manufacturers (1)	Carriers (2)	LSCs (2)
On-time delivery	80%	60%	100%
On-time pick-up	80%	49%	97%
Accurate billing	43%	54%	76%
Loss/damage experience	67%	48%	81%
Accurate documentation	*	41%	59%
Equipment cleanliness	*	35%	54%
Right equipment supplied	47%	31%	62%
n=	30	80	37

- Note:
- (1) By those 30 manufacturers participating in carrier performance monitoring programs and supplying report cards for review. Therefore the n is not equal to the full number of monitoring companies as the question was open ended. Other service elements monitored included, not in any order of priority: documentation accuracy, carrier financial data, carrier innovation, carrier safety record, carrier's membership in a quality program, carrier's responsiveness to programs, driver courtesy and/or appearance, and carrier's ability to offer EDI and/or container tracking and tracing. \* = less than 25% of the 30 contained this.
  - (2) By those 30 carriers participating in monitoring their own performance. In no particular order, other service points included cycle time, telephone accessibility/ease of contact, quality of telephone response/telephone etiquette, response time for booking or confirmation, call-back times, accounts receivable payment history, timely quotations, actual versus advertised transit times, wait time, driver appearance/attitude, and equipment delays. Those reported by only one company have not been listed.
  - (3) By those 37 LSCs participating in carrier performance monitoring programs, both with and without report cards to be reviewed with carriers. In no particular order, other service points included customer service response time, timely reporting and resolution of service problems, accurate tracking information, bar code scanning compliance, and driver appearance/attitude.

But what specifically is measured by carriers? Three of the seven report cards were customer satisfaction surveys, relying on the customer to evaluate the carrier's performance on subjective factors.

As for the LSCs, Brooks (forthcoming b) noted that there was remarkable consistency between asset-owning and pure service LSCs on the key service points that should be included in an effective monitoring system. On-time delivery is clearly critical, as are on-time pick-up and accurate billing, as can be seen from Table 9. Further, a number of firms stressed the importance of customer service response time and other customer relations factors.

## **Conclusions**

In the past decade, supply chain management has become a central theme in discussions about best business practices for many transport users seeking global competitiveness. It is critical that performance evaluation be implemented by users in today's consolidating transport supply environment. As the number of carriers decreases, those remaining in the marketplace need to be more closely examined to ensure that service needs are met in the face of fewer transport suppliers. However, in spite of all that appears in the trade press about the importance of performance evaluation to achieving the goal of sustainable competitive advantage through the extraction of both cost savings and service benefits to users, this research concludes that the reality of business practice does not match the perception.

Formal performance monitoring of transport suppliers is the purview of larger manufacturers. The same cannot be said about either carriers or LSCs. Carrier participation in systems monitoring own performance is high and the size of firms undertaking performance evaluation is quite diverse. It is difficult to draw definitive conclusions about logistics service firms, particularly given the poor response rate from U.S. companies and what appears to be the high turnover rate of such companies. However, it can be said that formal monitoring is being conducted by smaller firms.

The number of manufacturers employing quantifiable objective metrics was small and the metrics used appeared to be very company-specific. This was also true of the carrier respondents supplying report cards for review. The reliance of carriers on customer surveys and subjective evaluation was noticeable. Although it is true that customer satisfaction is an important element in assessing performance, it is insufficient as argued by Rhea and Shrock (1987). Surely, ten years later, performance evaluation in the age of carrier reduction strategies, outsourcing distribution and bar code and satellite information technologies would be further advanced. A rational review of superior service delivery should but may not result in a satisfied customer. Likewise, the existence of acceptable (to the carrier) customer satisfaction surveys

should not serve as an excuse for failing to evaluate performance and establish service delivery targets.

Second, contrary to expectations, many of the performance measurement systems reported were subjective rather than objective. The heavy use of subjective measures is disturbing. Continuous improvement is more difficult to effect if progress to date is not clearly defined. There is a common adage in the business community that "you cannot manage what you cannot measure." Quantifiable data challenges transport suppliers to improve their performance more so than any incentive derived from a subjective measure of that performance. At least, current performance metrics are in many cases customer-driven. Getting the right metrics is half the battle.

Third, the measurement of performance cannot be a one-time activity. The establishment of expected performance standards between the buyer and the seller sets the goal. However, expectations change over time and the standard should become a moving and improving target. Therefore, performance evaluation cannot be a snapshot but must be a planned activity. Otherwise, both the buyer and the seller are at risk from competitors who are able to exceed the expectations of the marketplace. Development of a planned program implies more than periodic audits, although they may provide the starting point for small firms due to their accessibility.

As a concluding comment, the carrier performance evaluation systems used by logistics service firms need further examination. It is disappointing that the planned assessment of differences between LSCs in this research program was limited by non-response bias. As 53% of the carrier respondents indicated that they act as logistics service firms and approximately 40% of LSCs replied that they own transport assets, these two groups may have quite different approaches than evident in this study. Asset-owning logistics providers have an inherent potential conflict between their customers' interests and their own (Sheffi, 1990). The true nature of the relationship between third party logistics suppliers and their carrier company partners is clearly a matter for further investigation.

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**WHAT AIRPORT FOR THE FUTURE?  
VALUE ADDED, DURABILITY AND COOPERATION**

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*For every complex problem there is a simple, easy to convey, wrong solution  
(Henry Louis Mencken, 1880-1956)*

## **1. A SIMPLISTIC GROWTH MODEL OF AIR TRANSPORT**

The stage for discussing both the future of air transport and airports is usually set by a simplistic model of extrapolated growth of volumes (number of passengers as well as tons of freight). According to IATA passenger transport, for example, is expected to grow till 2015 world-wide at an average annual growth rate of approximately 5%. Individual airports may grow faster or slower. A simple extrapolation of their present growth would imply a fallacy of disaggregation as it does not take into account the competitive positioning of airports (more about this in section 3).

If air transport is measured in terms of number of flights (transporting either passengers or freight) between origins and destinations, a simplistic approach to airport performance - counting only the number of passengers or tons of freight per airport - causes "double counting". Or even "quadruple counting" in the case of transit. The latter can be an important phenomenon as in the case of Schiphol with the transit shares of almost 50% and 60 to 70% in respectively passenger transport and freight transport.

An origin destination matrix of passenger and freight flights including transit and containing information on respectively passenger- and ton-kilometers, provides a more accurate picture of air transport. It is important to gain insight into complete chains extending, ideally, to transport to and from airports. The problem is similar to the modeling of European freight transport (NEA, 1995). Especially congestion, say within the European Union, requires insight into interconnections at a higher level of aggregation than that of individual airports.

Extrapolated growth of volumes is just one side of simplicity, the other side being the assumption of simple relationships between on the one hand, growth and the benefits and costs of air transport, on the other. Economic-benefit and social-cost arguments are more important in discussing the airport for the future than arguments related to either social benefits or economic costs.

### **1.1 Economic benefits**

In this day and age, economic benefits are usually measured in term of employment. This is, however, not the only possible economic indicator and may not even be the most important one, compared to value added.

Evaluators usually distinguish the economic effects into:

- direct effects: employment created by airport- or platform- bound activities (which, in turn, are related to volumes of passengers and freight),
- backward linkages: employment created by the suppliers of goods and services related to platform-bound activities,

- forward linkages: the persons employed by companies the functioning of which relates to the airport and for which the airport has been an important location factor.

Direct effects are straightforward. So are backward linkages, although indirect in nature. This is not true for forward linkages, however.<sup>1</sup> They are difficult to quantify and it is also difficult to assess the importance of an airport as a location factor. A survey of factors influencing recent location decisions has shown that mobile investment<sup>2</sup> in Europe, as a matter of course, depends on a variety of factors: business factors, national and local characteristics, labor factors, cost factors, infrastructure, quality of life and personal factors (Commission of the European Communities, 1993). The proximity to a major airport is one among many influences, being only one of the infrastructure factors. "No simple model can be constructed of location determinants". But if one singles out "proximity major airports", the results shown in table 1 emerge.

**Table 1. Companies identifying 'proximity major airport' as critical or important to choice of region**

	Critical	Important
Manufacturing plants	6 %	31%
Offices	46 %	15 %
Distribution activities	25 %	25 %
Services	7 %	40 %
R&D activities	-	-

Source: Commission of the European Communities, 1993, 78, 83, 86-88.

As far as future developments are concerned, proximity to airport is expected to be of critical, increasing importance for the location of European headquarters, European distribution and services as well as increasingly important with regard to high-tech manufacturing and R&D.

The question, however, is what is to be considered as a "major" airport. Certainly, international connections are an important feature, but at what level? Do only Intercontinental gateways (ICAs) in large domestic markets such as Heathrow or Frankfurt qualify as major airports? Or does it suffice to be an airport in a medium-sized market without hub dominance such as Manchester? It should be noted that these are just the top and bottom positions of a present typology of airports (see section 3).

A recent regional breakdown of mobile investment-location decisions is not available, but these decisions hardly favor exclusively the Southwest of England, the Rhein-Main area or Ile-de-France for that matter. And, as mentioned before, the proximity to a major airport is only one among many factors influencing location decisions.

It becomes clear that the relationship between growth of volumes and economic benefits is far from simple. What about the social or external costs of air transport?

<sup>1</sup> For airline and airport costs see e.g. Caves (1997).

<sup>2</sup> Including the creation of a new establishment, expansion in existing premises, opening of branch plant, migration, transfer of part of the activities to another establishment within a multi-plant company, contraction or even closing down.

## 1.2 Social costs

The costs caused by air transport, but usually not included in the price of air transport, are manifold. These external costs include:

- noise and atmospheric pollution caused by aircraft operations,
- atmospheric pollution caused by airport vehicles or other airport-related sources such as power stations,
- land-use, soil erosion and water pollution caused by the development of airport and airport-related infrastructure (including barrier effects, loss of landscape value and disturbance of ecological system),
- water and soil pollution caused by inadequate treatment of airport-related effluents (fuel, de-icing products and lubricants),
- operational and waste discharges,
- risks inherent in the transport of dangerous goods, aircraft accidents or emergency landing procedures,
- congestion (land-side access; delays/time costs imposed on others),
- energy consumption contributing to the exhaustion of fossil fuel (in the long run).

The magnitude of the social costs depends, among others, on the way they are measured, only locally or on a larger scale.

Noise, for example, can be measured using contour lines taking into account the number of airplanes, their noise level and the point in time (day versus night). Contour lines can then be converted into norms which is, in fact, a political decision fixing acceptable or unacceptable levels of nuisance. Night flights, e.g., produce more nuisance than day flights. Or an even larger scale, the social costs of air transport can be related to the entire passage between origin and destination, especially if one considers the greenhouse effect or acidification as important environmental issues. Ideally, an origin-destination matrix of passengers and freight flights should be translated into some kind of environmental impact matrix. Anyway, the measurement of external costs is to match the measurement of economic benefits distinguishing not only direct effects, but also backward and forward linkages such as the transport of both passengers and freight to and from airports (land-side access). As a result, this transport becomes intermodal. Take, for example, air freight trucking. Congestion around airports, especially where airport-linked traffic meets with other-directed traffic, can even influence economic benefits in a negative way by reducing the attractiveness of major airports as location factors.

The picture of the relation between growth of volumes and social costs, too, is a complex one.

Simplification can take various forms. Evaluators can leave out important categories of social costs. Measurements can be restricted to local effects. And one can ignore backward and forward linkages. On the other hand, it seems questionable to base the measurement of social costs simply on volumes of passengers and freight or even the number of flights. In doing so one neglects intervening variables such as types of airplanes (e.g. ordinary versus "silent" engines), load factor, use of runway, take off and landing procedures, fly-in and fly-out routes.

When it comes to decisions on building new airports or expanding existing ones, more often than not, a simplistic growth model of air transport is used to appraise the pros (economic benefits) and cons (social costs), confronted with the investment required. An overestimation or underestimation of either benefits or costs can tip the balance. Take, for example, the inclusion of the “backward linkages of forward linkages”: among others, employment created by the suppliers of goods and services related to activities connected to the airport and for which the airport has been an important location factor. Or the neglect of intervening variables in measurements of external costs. In the end, however, the choice may be presented to decision makers as a simple dichotomy between “economy” and “environment”.

Given the importance of the investments at stake, the evaluation presented itself needs to be evaluated (Commissariat Général du Plan, 1994).

### 1.3 Beyond simplicity

From a scientific point of view, however at least, three issues are essential. The simplistic growth model of air transport tends to ignore the existence of both major uncertainties and limits to growth. It also assumes that the future will bring more of the same, which is another way of saying that it ignores or underestimates major innovations ahead.

First, there is no such thing as “perfect knowledge”. The evaluations of airport projects or airport expansion plans are based on the assumption that the positive impact on regional (national) economic development of air-transport infrastructure and services is unequivocal (Pols, 1997). This assumption, however, is not or at best scarcely corroborated by empirical evidence. A yet unsolved question is that of the direction of causality. A positive impact on air-transport infrastructure and services of regional (national) economic development is equally plausible for the time being. Moreover an S curve seems to be a more adequate presentation of the relation between growth of GRP and growth of regional infrastructure network. The more (less) developed the network, the lower (higher) the economic returns (including the forward linkages) - other things being equal. Conversely, additions to an already highly developed infrastructure network may produce disproportional high social costs in densely populated regions such as the airport triangle of Paris-London-Frankfurt or the Randstad Holland. There are also doubts as to whether the forward linkages represent additional growth in the airport region or just a spatial redistribution of economic activities already existing in other parts of the country in question (or the European Union for that matter). Simplifying things (again), forward linkages may be treated as a catchall for autonomous growth, additional growth and distributive effects.

Summarising the state of art of scientific evidence, one can hardly ignore the existence of a major uncertainty.

Next we come to limits of growth. Assuming, as IATA does, that passenger transport is growing exponentially at a rate of 5% till 2015, implies that passenger transport is going to double worldwide within some 14 years. Air freight transport could even grow faster if there were no restrictions on night flights. As the growth of passenger transport, too, meets

with constraints<sup>3</sup>, one has to face airport congestion. Again according to IATA, this prospect holds for 50 of the largest airports in the United States and Europe. Others expect the number of passengers of European airports to double till the year 2010 with 29 out of 33 of the largest airports having to contend with congestion. Of course, these limits to growth could be “assumed away” postulating that airports are open 24 hours a day or any other constraints caused by air transport policy will be abolished and that the required expansion of infrastructure (runways and terminals) will be provided in time. A limit, more difficult to assume away, is the exhaustion of fossil fuel-unless one adopts a short view. Compare table 2 for the average energy consumption per passenger-kilometer<sup>4</sup>. The sustainability of air transport, however, not only depends on this aspect, but also on the amount of other social costs, in fact, on the entire range of social costs listed above.

**Table 2. Average energy consumption per passenger-kilometer and mode of transport**

Walking	r	.16 MJ/passenger-km
Bicycle (15 km/h)	r	.06 MJ/passenger-km
Bicycle (27 km/h)	r	.10 MJ/passenger-km
Bicycle (44 km/h)	r	.14 MJ/passenger-km
TGV	pr	.74 MJ/passenger-km
Interregional train	pr	.82 MJ/passenger-km
Subway, local train	pr	1.03 MJ/passenger-km
Automobile	nr	1.70 MJ/passenger-km
Bus	nr	.87 MJ/passenger-km
Airplane	nr	2.20 MJ/passenger-km

r = use of renewable energy

pr = use of partly renewable energy

nr = use of non-renewable energy

Source: Hourcade, 1996, 90

Finally, there is the question whether there are not major innovations ahead challenging the implication of the growth model of air transport that the future will simply bring more of the same. While major technological breakthroughs, beyond nature and medium-term technologies, are not to be expected for the time being, the whole “environment” of air transport certainly will undergo important changes. Take only the new trends in freight transport (Ruijgrok et al., 1991). In this paper the focus is on the role of logistics. This includes the use of IT or ICT for far-reaching management and control of production and transport flows.

The complexity and uncertainty in air transport ask for scenario planning (Schwartz, 1991). In dealing with structural change in world-trade flows, three scenarios have been elaborated:

- “global village” (the world-wide liberalization makes it easier to export from one location to the rest of the world),
- “global recession” or “global crisis” (an economic crisis leads to a regionalized production, but may also cause its centralization in the most productive locations),
- “greening of business” (a stronger emphasis on the environment will probably lead to less transport and hence “glocalization”; some production processes, however, from a

<sup>3</sup> In especial capacity constraints related to land-side access, air-side access and ground infrastructure (the latter comprises runways, aprons, terminals and ATC infrastructure).

<sup>4</sup> It is also interesting to compare the direct energy costs of different transport modes with those of telecommunications (Tuppen, 1992) which has bearing on the so-called telecom/transportation trade-off.

global environmental policy point of view, might also be served by world-wide centralization).

These scenarios have different impacts on air and sea transport as has been shown for the Netherlands (Junne et al., 1996; Drewe and Janssen, 1996). Similar scenarios may hold for air transport. The growth model of air transport stands and falls with the global-village scenario. The other two scenarios both imply lesser volumes, though for different reasons. Greening of business is also related to the way in which the social costs of air transport are treated (more about this in section 4).

## 2. THE POSITIONING OF AIRPORTS

The positioning of airports is always hierarchical. And hierarchy breeds competition for market shares.

There are different ways of classifying airports. Take for example the Trans-European Airport Network which consists of three types of airports:

- Community connecting points,
- regional connecting points,
- accessibility points.

Back in 1993, this network consisted of 237 airports, of which 40 community connecting points, 60 regional connecting points and 137 accessibility points (European Commission, 1993). The typology is primarily based on passenger movements, commercial aircraft movements or tons of annual freight throughput. Air traffic is concentrated on the Community connecting points. In 1993, their total annual throughput has represented 75% of the total passenger volume, 91% of extra-Community traffic and 70% of intra-Community (including national) traffic. By the way, most of the traffic handled by the total network was either national (36%) or intra-EC (25%) with "only" 29% international.

**Table 3 Present typology of airports plus some examples per type**

	USA	Europe
Intercontinental gateway (ICA) in large domestic market	JFK Chicago	Heathrow Frankfurt
Second airport in large domestic market	La Guardia Newark	Gatwick Orly
Intercontinental gateway (ICA) in medium-sized domestic market	- -	Schiphol Zurich
Continental hub with moderate ICA-function	Dallas/Fort Worth Atlanta	Brussels Copenhagen
Continental hub with limited ICA-function	Charlotte Pittsburgh	Munich Düsseldorf
Airports in medium-sized markets without hub dominance	Boston Orlando	Manchester

Source: Bleumink et al, 1995, 80

Table 3 gives another example of the positioning of airports, referred to earlier. It results from a study of 40 US- and European airports. The typology is based on passenger



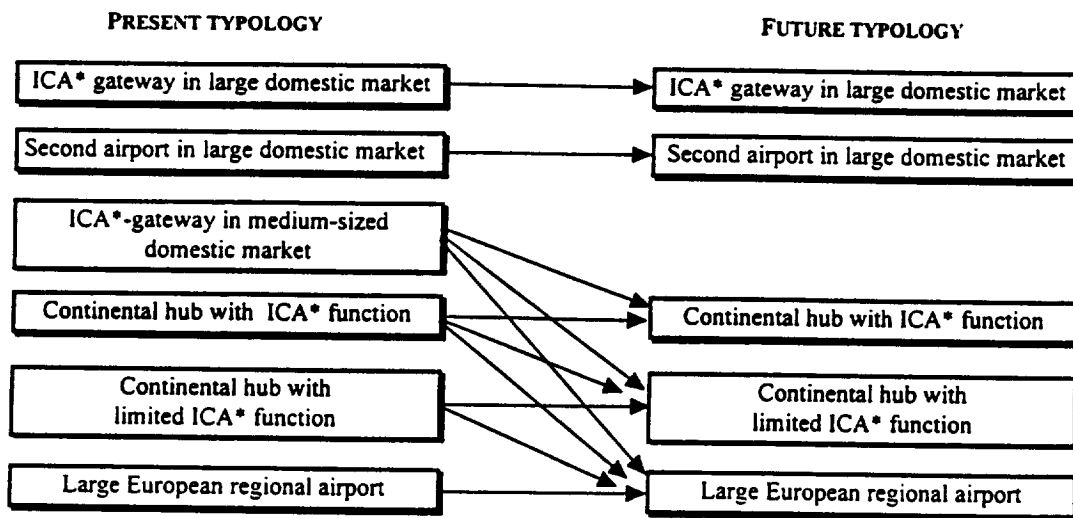
transport (with freight transport being considered as an important by-product). There are three criteria:

- (continental) hub dominance on airport by one or two airlines,
- intercontinental function of airports (ICA function),
- size of domestic market.

According to these criteria, airports range from intercontinental gateways (ICA) in large domestic markets down to airports in medium-sized markets without hub dominance. A few characteristic examples of each type are given both for the United States and for Europe.

The present typology is expected to change in future, in particular in Europe thanks to the liberalization of the air transport market. Figure 1 refers.

**Figure 1. Possible changes of European airport typology in a liberalized air transport market**



\* ICA = Intercontinental function

Source: Bleumink et al, 1995, 80.

The two top positions are expected to remain constant. So is the bottom position. Continental hubs may either maintain their present position or be reduced to a lower rank. ICA gateways in medium-sized domestic markets are the most vulnerable type of airport risking "degradation". What about Schiphol's future position for that matter? Is it going to become a continental hub with an ICA function, as main hub of large airline? Higher ambitions seem to be thwarted by a limited domestic market. Or can a further increase of transit traffic make up for this handicap?

The criteria for positioning airports, both at present and in the future, are rather simple. They are either volume-oriented (size of domestic market) or supply-oriented in terms of types of origins and destinations (continental and intercontinental) offered by the airport or the airlines operating from it. Hub dominance refers to the hierarchy of airports, i.e. their degree of centrality in an international network of airports. The positioning approach can

be summarised by the following equation, similar to the conventional positioning of seaports<sup>5</sup>:

$$M.T = Co.Q$$

where:

M = mass of freight and passengers to be transported per airport

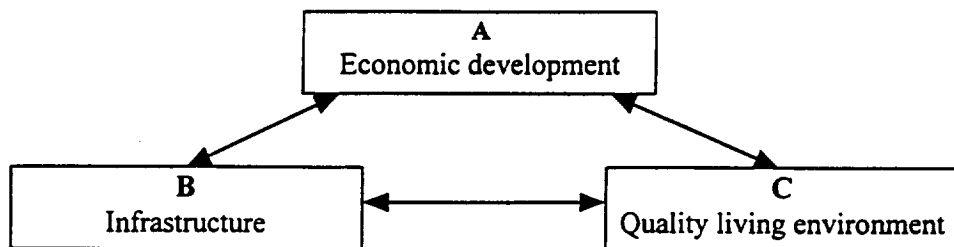
T = type of airport (as in table 3, 5)

Co = transshipment/transit costs in airport in relation to competing airports

Q = quantity of freight and passengers transhipped in airport

If the typology of airports (T) would change, more in line with the complexities revealed by the foregoing analysis of economic benefits and social costs, this would position airports within a triangle of economic development (A), infrastructure(B) and living environment (c). As a consequence, decisions on building new airports or expanding existing ones turn into problems of optimizing the three components - even if one starts from the priority of economic development as in the so-called growth-management approach (figure 2).

**Figure 2. Growth management of airports: the policy triangle**



Source: Draijer, 1996, 14.

### 3. THE ROLE OF LOGISTICS: A DOUBLE IMPACT

In the foregoing section, the positioning of airports has been summarized by a simple equation. The impact of (product channel) logistics on this kind of approach is twofold. On the left-hand side, the emphasis is shifting from physical accessibility to controlled and dedicated logistic accessibility (facilities and services). And, as far as the right-hand side is concerned, “tonnage thinking” is replaced by “chain and value-added thinking”. The focus is on the transport of goods. However, the new reasoning can also be applied to passenger transport. But in order to set the scene, recent trends in European logistics need to be described first.

#### 3.1 Logistics: recent trends

The 1980’s and 1990’s have been a period of extensive change in European logistics. Many companies have, in response to a changed business environment, restructured their physical

<sup>5</sup> With the exception of T replacing C, the centrality index of seaports. C measures the infrastructural access of ports to their hinterland by rail, road and inland waterway, i.e. its multimodal physical accessibility.

distribution networks. The removal of barriers means that is increasingly possible to internationalize rationally and economically and to achieve geographical integration in logistics, with operations spanning country borders. The single European production plant is no longer a rare phenomenon. There is a strong tendency in industry towards specialized production sites, serving the European and even global markets within a company's broad range of products. The number of factories and warehouses dedicated to within-country production and movement has been reduced. Cross-border sourcing and deliveries have increased. The number of regional warehouses serving more than one country has grown extensively (Janssen et al., 1995).

Logistics at the firm level has developed from mere logistics, with its emphasis on modal rate and modal cost, to product channel logistics, meaning cross-border coordination of the management of materials and finished goods, from the sourcing of raw materials to the point of final consumption (Janssen, 1993; Ojala, 1997). At the heart of the new logistics is the idea that the materials flow that links the firm with its market and its suppliers must be managed as an integrated system, and no longer on a functional basis. Product channel logistics extends the benefits of internal integration outside the firm into geographical integration, i.e. the logistic integration of operation across national boundaries. As a consequence, we can witness today in Europe the development of a geographical model of implantation of plants specialized in the production of one or two finished products, or a maximum range of similar finished goods (Bonnafous, 1993). The complete range of products of a company is produced in different plants, mostly in different countries. This model also holds for plants for production of intermediary goods. Plants and distribution centers serve larger markets than before.

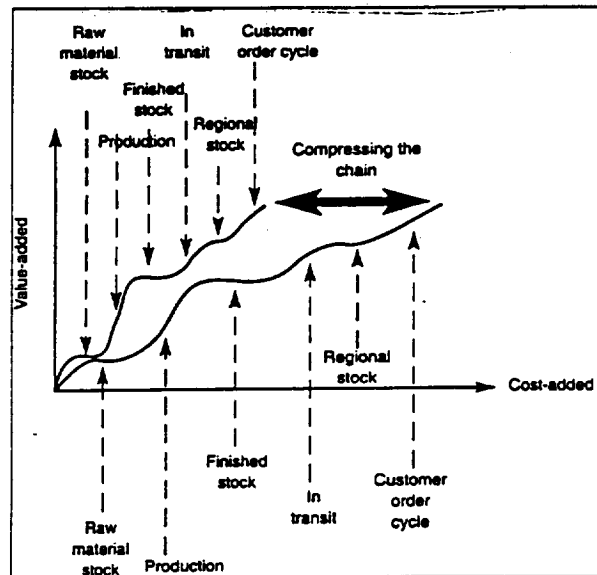
The outcome of this logistic geographical restructuring process, along with the tendency towards "lean and mean production" (Harrison, 1994) and just-in-time logistics, is that goods are not only transported over longer distances, they are also being transported in less bulky quantities. Finished goods are distributed over greater distances than the supply of intermediate goods, which in their turn are destined to serve more plants at distances much larger than in previous years. Road transport is the highly favored mode (NEA, 1997a).

### **3.2 From physical accessibility to logistic services**

What are the most important driving forces in European logistics? Changes in customer service needs are considered to be by far the most important driving force across different business sectors, across all sizes of business and irrespective of the region of location of business activities. In a survey of more than 300 large companies in Europe, 51% of the companies ranked first the changing customer service needs. Developments in information and communication technology (ICT) is second in importance, ranked first by 15% of respondents. ICT is seen as enabling the developments in European logistics, but also as hampering the speed with which benefits of European logistics can be realized. Other important factors mentioned are the growth of the third-party logistics services sector, the development of multi-national retail groups, environmental pressure and transport capacity constraints (European Logistic Consultants, 1996).

As a result of these changes, managers try to compress the logistic chains. The advantages are decreasing costs and, at the same time, maintaining or more preferably increasing value-added. Figure 3 illustrates the goal of strategic logistic management: to compress the logistic chain in terms of time consumption so that cost-added time is reduced.

Figure 3. Compressing the logistic chain: cost-added versus value-added



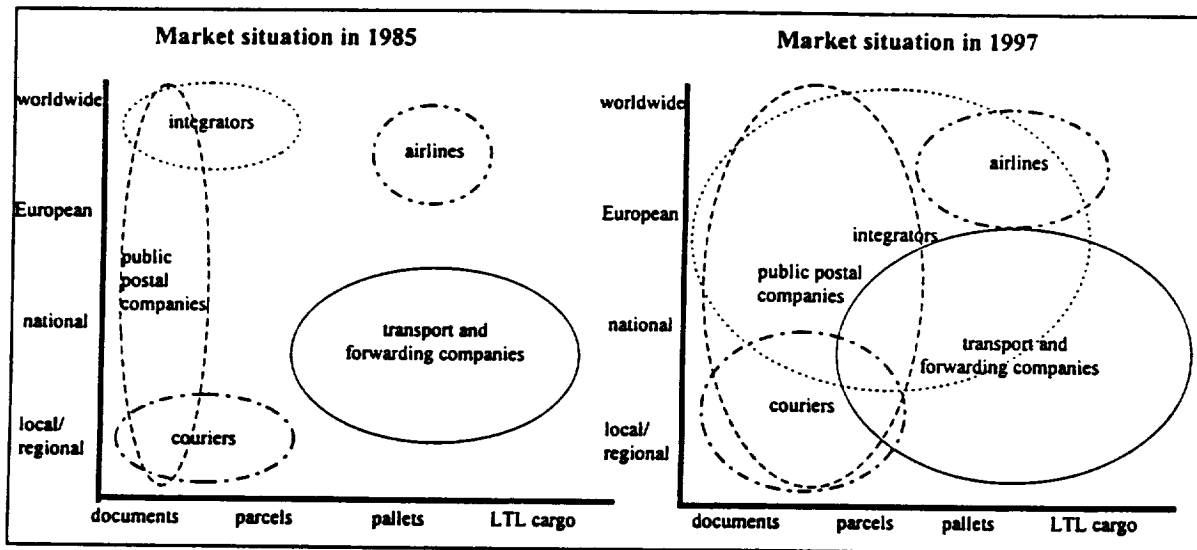
Source: Christopher, 1992, 137

Product channel logistics has become one of the leading logistics strategies. It is expected to be developed further in the future (Cranfield et al, 1992; European Logistic Consultants, 1996). Product channel logistics will strongly influence the behavior of logistic services providers and therefore will have a strong influence on the type of services they require from airports. To carriers, the emerging customer service requirements are directly translated into more time pressure and higher reliability and quality requirements. The emphasis has shifted from product profitability and transactions to building long-term relationships with customers, from profit focused around margins to customer profitability. Modularization of load units is necessary to combine quality requirements and to achieve the necessary cost reductions. Multimodality and intermodality have become important concepts. Load and vehicle identification techniques, telematics, smart cards and communication and information technology make it possible to manage logistic systems in real-time, or approaching real-time.

Logistic service providers are forced to develop differential strategic responses with regard to specialization and integration (NEA, 1997). More types of logistic services are offered while, at the same time, the geographical coverage of services is broadened. Air cargo transports and more in particular express cargo are integrated into the logistic concepts of shippers. The high costs of express cargo services are more than compensated for by the reduction in other logistics costs such as inventory costs. Express cargo shipments today are for more than 90% planned shipments and not restricted to documents, highly perishable goods or spare parts. There seem to be no longer any restrictions with regard to weight or volume. "Integrators" such as UPS, Federal Express and TNT-KPN are investing

heavily into their networks and IC-technology and are becoming strong players in the field of value-added logistic services as there are dedicated and public warehousing, orderpicking, after-sales services. “Conventional carriers”, on the other hand, are offering today services with logistic characteristics formerly restricted to express services (high frequency, high reliability). Apart from the air freight carried directly by the integrators, i.e. with the use of their own equipment, almost 95% of this traffic is in the hands of other logistic services providers, especially the forwarders who play a crucial commercial role in the logistic networks of their customers, the consignors. It can, however, be argued that in the very near future, integrators will take over a considerable part of this air freight market by providing door-to-door services. Figure 4 shows the differences in market situations of the express market in 1985 and 1997.

**Figure 4. Activity packages of suppliers of express services On the European market, 1985 and 1997**



Source: Adapted from Van Riet and Ruijgrok, 1996

About two thirds of air freight is carried on passenger aircraft. Airlines still are important players in express and intercontinental air freight. They, however, do not have the necessary ICT-systems or networks to offer door-to-door services and to cover every region (European Conference of Ministers, 1997, 104-105). Airports as nodes in logistic networks are necessary in order to achieve the required scope in connecting multiple origins and multiple destinations with high frequencies.

As to the air transport of passengers, the emerging approach of “seamless multimodal mobility” could be of interest. Even if it is still a research program (Bovy, 1996). The general idea is to design unprecedented multimodal personal travel services in an ubiquitous information environment.

The future transport system will be an integrated, flexible multi-layered network of various types and forms of transportation services, linked together in intermodal transfer nodes. This service network is supported by physical infrastructure links and nodes as well as

extensive ICT networks for travelers, service providers, vehicle drivers and public transportation operators. Essential requisites for attractive multimodal trips' chains are:

- provision of well-designed multimodal transport services networks;
- availability of omnipresent up-to-date information in behalf of travelers, integrators (professional trip chain organizers) and transport operators;
- perfect coordination and control of individual trip chains;
- high performance and infrastructure facilities, especially intermodal transfer points.

Air passenger transport of airports for that matters, could be dealt with as an integral part of a seamless, multimodal trip chain.

### 3.3 From tonnage to value-added

The shift from “tonnage thinking” to “chain and value-added thinking” can be illustrated by experience from seaports. As a first step, freight volumes are to be divided into segments and the (gross) value added per segment per ton is to be calculated. Take Rotterdam as an example:

1 ton of conventional cargo = 2.5 tons of oil products = 3 tons of containers = 4 tons of cereals = 7.5 tons of other bulk = 8 tons of ro/ro = 10 tons of coal = 12.5 tons of ores = 15 tons of crude oil (this is the so called Rotterdam rule).

The basic reasoning then is that it is possible to create the same amount of value added or even more value added by shipping lesser volumes of goods. To wit, a shift from crude oil to conventional cargo reduces the volume from 15 tons to 1 ton, producing the same amount of value added. Similarly, only two tons of conventional cargo suffice to double the value added produced by the shipping of 15 tons of crude oil.

In order to apply this kind of reasoning to air freight, one needs to identify the relevant segments of goods transported by air.<sup>6</sup> The concept of the “air-freight cube” appears to be a useful tool. Whether a product should preferably be transported by air, is determined by three factors, its

- value density (value of product per unit of volume, say, 1 m<sup>3</sup>),
- urgency of transport (emergencies, perishable goods etc.),
- volume density (the volume/weight ratio - i.e. cubic meters divided by kilograms - in relation to the suitability of products for stacking).

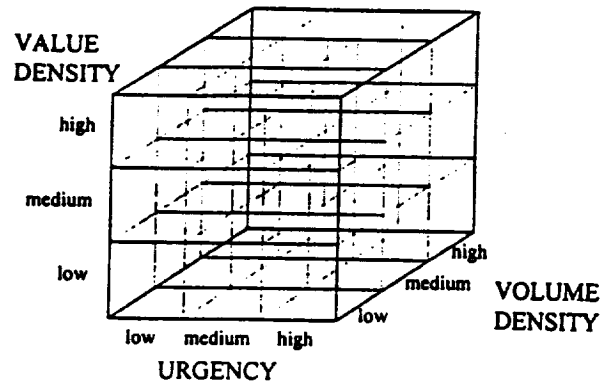
Each factor can be divided into three positions: high (large), medium and low (small). Together, they form a cube composed of 27 subcubes. See figure 5.

It should be noted, that the value density of a product is related to its position in the logistic chain. Urgency can also be seen as an expression of lead time, the time interval between the placing of an order and delivery, which is a basic concept of logistics.

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<sup>6</sup> Measured in terms of Work Load Units (WLU), defined as one passenger movement or 2000 lb or pounds of cargo.

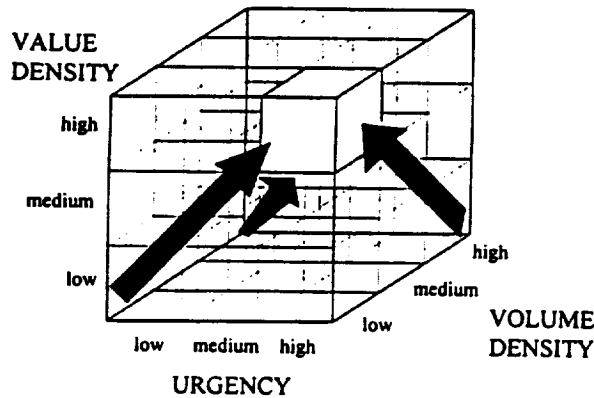
**Figure 5. The air-freight cube**



Source: Junne et al., 1996, 18.

Unlike sea transport, heavy, non-perishable goods with a relatively low value density are usually not transported by air. The optimal situation is reached when value and urgency are high, but volume density is low (figure 6). A situation which corresponds to the shift from tonnage to chains and value added.

**Figure 6. The optimal subcube**



Source: Junne et al., 1996, 19.

Whether a product is actually transported by air, eventually, is decided by an interplay of demand (business firms) and supply (airlines). This does not prevent suppliers of air transport services, however, to focus more on chains and value added.

To shed more light on the air-freight cube, let us take a look at four selected product groups representing the bulk of (intercontinental) freight transport in the Netherlands: cut flowers; electronics and machines; textiles and clothes; agricultural and horticultural products. The results are shown in table 4. Electronics and machines are broken down by position in the production (logistic) chain which has an impact on the three determinants.

**Table 4. The air-freight subcubes of selected product groups in the Netherlands**

Product group	Value density	Urgency of transport	Volume density
• cut flowers	medium	high	medium
• electronic & machines:			
raw materials	low	low	high
standard components	low	low/medium/high	low
customized components	high	high	low
assembly products	medium/high	high	low/medium
end products	high	high	high
after-sales and repair	medium	high	low/medium/high
• textile & clothes:			
in general	medium	low	medium
fast delivery	medium	high	medium
• agricultural & horticultural products:			
French beans	high	high	low
paprika	high	medium	medium

Table 4 describes the present situation. But the air-freight cube can also be used for analyzing potential future developments, trying to identify products that are moving toward the optimal situation: products marked by an increasing value density and urgency combined with a decreasing volume density, generally speaking. Of course, other factors come into play, too (e.g. new forms of substitution, especially between air and sea transport). Moreover, company strategies can create new flows of air freight, strategies such as specialization<sup>7</sup> and scaling-up (on the supply side) as well as world-wide “sourcing” and selling (on the demand side). Altogether future developments, however, will be subject to uncertainties. The scenarios sketched in section 1 refer. Instead of using the air-freight cube as a tool of analysis, one could also apply, for example, the so-called logistic-family concept:

“A logistic family is a group of products sharing similar product and market characteristics, underlying similar logistics decision making. It is a method aimed at logistic segmentation” (Kuipers et al, 1995, 55).

The characteristics are: value density, package density, keeping quality, market range, market scope, client density and demand frequency.

So far we have only dealt with air freight. But what about passengers? What we are looking for is a segmentation of the air passenger's market that takes into account differences in value added. Relevant types of passengers to be considered are, for example: non-stop versus stop, business versus economy class, scheduled versus charter flights, continental or intercontinental destinations versus transit. One could think of constructing some kind of “air-passenger cube”<sup>8</sup> or, at least, set up the “Schiphol equivalent” of the Rotterdam rule (of thumb). These tools may help to answer the basic question: is it possible to produce the same amount of value added or more value added by transporting lesser numbers of passengers? Airline strategies could be focused accordingly, catering to the needs of

<sup>7</sup> Special products, e.g. according KLM Cargo: valuables (art, diamonds), perishables (vegetables, fruit, flowers), living animals, medicals & chemicals.

<sup>8</sup> Comprising e.g. value per passenger, some kind of passenger volume density and, may be, flight frequency. Whether a cube is the most appropriate tool, depends of course on the number of relevant dimensions.



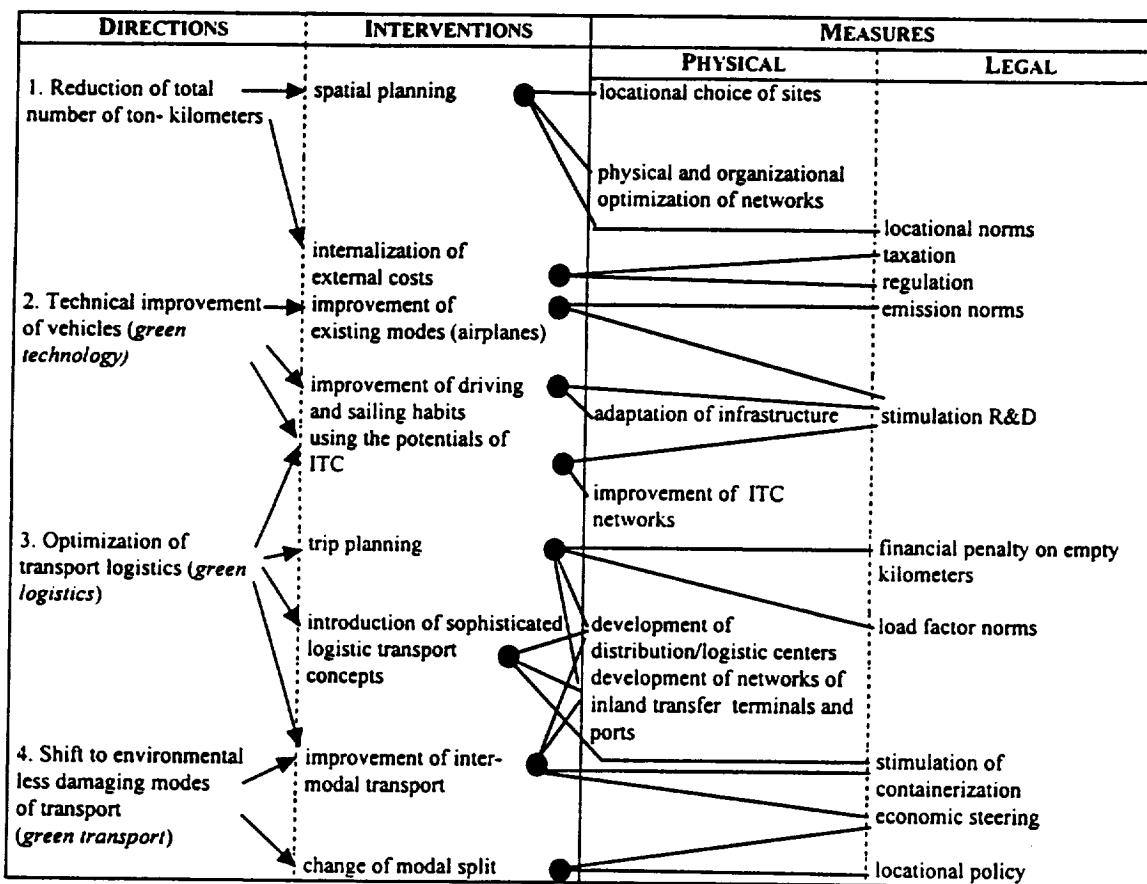
specific passenger segments. Market research can teach us what a target group values most. As far as business travelers (in the Netherlands) are concerned it is: speed, advantageous fares, suppliers helping to think of solutions, speedy dispatch, flexibility, up-to-date information, round-the-clock accessibility (in descending order of importance).

And finally, there is also the possibility of combining freight and passenger strategies as in the case of belly-and combi-freight.

#### 4. THE SOCIAL COSTS OF AIR TRANSPORT: 'ONLY VARIETY CAN DESTROY VARIETY'

The different social costs of air transport have already been dealt with in section 1. Given the complexity of the problem, there are no simple solutions. One has to consider various ways of reducing the damage caused by air transport, various interventions and measures as in the case of freight transport in general. Table 5 provides a frame of reference for the discussion of air transport.

Table 5. How to deal with the social costs of air transport



Source: adapted from Verhagen, 1994

#### **4.1 Reduction of total number of ton-kilometers**

A strategy focusing on value added rather than on tonnage, may lead to a (selective) shrinking of the total number of both passenger- and ton-kilometers. But from the vantage point of social costs, one can also think of spatial planning interventions and, in particular, the internalization of external costs.

Spatial planning, implying a locational policy and locational norms, applies primarily to the physical expansion of existing airports or the construction of new airports: reducing further growth of passenger- and ton-kilometers. If for example contour lines of noise are enacted and carried out, this too can limit further growth. Internalizing the social costs of air transport requires at policy at the Community level. In fact, the Directorate-General for Transport has already announced its policy intentions in this area (European Commission, 1996). The policy options aiming at fair and efficient pricing in (air)transport relate to internalizing:

- costs paid by others (with regard to transport expenditure: such as tax exemption of fuel and tickets),
- uncovered infrastructure costs (such as the provision of extra land-side access to airports),
- uncovered accident costs (e.g. pain and suffering imposed on others),
- uncovered environmental costs (such as air pollution, noise; also environmental tax exemption of transit passengers),
- delays/time costs imposed on others (due to land-side access congestion).

#### **4.2 Technical improvement of vehicles**

Vehicles in our case are basically airplanes. But it can also be trucks as in the case of air-freight trucking. Technical improvements are mainly twofold. They can aim at airplanes ("silent" engines, fuel efficiency or reduced emissions) as well as their "driving" and sailing habits". The latter includes changes in use of runway, takeoff and landing procedures, fly-in and fly-out routes, among others. Moreover, there may be potential uses of information and communication technologies to be explored.

#### **4.3 Optimization of transport logistics**

Interventions under this heading target a more efficient use of vehicle-kilometers through:

- using the potentials of ICT (e.g. for improving the performance of air control),
- trip planning techniques ("fuller", "less empty", "bigger"),
- introduction of sophisticated logistic transport concepts (as referred to in section 3.2),
- improved intermodal transport (which also figures under the next heading).

#### **4.4 Shift to environmentally less damaging modes of transport**

There are two ways of achieving such a shift. One is improving intermodal transport, the other changing the modal split. They can be interrelated when air-rail connections are made "seamless" thus producing a shift from air-road to air-rail transport of both freight and

passengers. A change in modal split can occur between air and sea transport in the case of freight transport. Opportunities for this could be found as one moves towards the lower left-hand corner of the air-freight cube. More important, however, seems to be a shift from air to rail, i.e. substituting rail transport for air transport.<sup>9</sup> This depends largely on the development of high-speed train links. The distance at which substitution is considered as a real option lies between 200 and 800 kilometers as far as passenger transport is concerned. At a distance of 460 kilometers, there is no difference in travel time between TGV and airplane. Traveling by TGV, however, is about 40% cheaper. An experience often quoted is the TGV link between Paris and Lyon, created in 1983. As a result, air transport between these cities has been reduced by 60%. But it is also possible that this kind of substitution is thwarted by low-cost carriers that are able to carry out direct inter-city flights in a competitive way. High-speed train links can also serve for transporting goods. In the longer run, one can even think of a European high-speed rail net (NEA, 1997). This option implies either a shift from air-road (air-freight trucking) to air-rail or from air to rail. The former would also lessen land-side congestion.

If actions are taken to cope with the social costs of air transport, this would mean the end of the simplistic growth model which is basically a laissez-faire approach. The future growth of air transport would be constrained both directly (in particular through taxes and higher prices because of higher "total visiting costs") and indirectly (through local environmental and capacity limits). On the other hand, the same of interventions, listed in table 5, open up new options. This holds for technical improvements of airplanes (including the improvement of their "driving and sailing habits"), the optimization of transport logistics and a shift to environmentally less damaging modes of transport comprising improved intermodal transport. It is essential to stimulate research and development in these areas.

If actions directed at the social costs of air transport are combined with logistics strategies in general and those focusing on value added in particular, then a policy of selective growth and shrinkage becomes possible (Pols, 1997). This is a far cry from a simple dichotomy between "economy" and "environment". Of course, to move from a simplistic model of extrapolated growth of volumes to "organized complexity" (Jane Jacobs), requires a major effort.

## **5. Airports: from competition to cooperation?**

The European market for air transport will undergo substantial changes with the forthcoming liberalization and privatization. For decades, air transport has been subjected to state regulation with regard to market entry, routes, capacity and fares. National airports and national airlines have been subsidized by their governments. But national airports and national airlines will have to go as airlines within the EU will become free to choose their own network of routes to be served. The Trans-European Airport Network of 1993

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<sup>9</sup> It can be useful to compare both modes with regard to energy efficiency as a function of speed, atmospheric pollution per ton-kilometer, space consumption per passenger-kilometer, external costs per passenger kilometer. Except for lead and SO<sub>2</sub> emissions as well as accidents, rail transport is superior to air transport. See Hourcade, 1966.

comprises 237 airports out of a total of 313 all of which have been presented by the member states as airports of “national interest”.

Will deregulation bring more unchecked or even cut-throat competition with only the most efficient, commercially operating companies being among the survivors and the losses being counted as another social cost? And if the construction of new airports or the expansion of existing ones is meant to produce a competitive advantage in one case, will this advantage not be nullified by similar projects elsewhere? Isn't the economic and social cohesion in the Community at stake here? And what about strengthening the competitive position of EU airports vis-à-vis non-EU airports when open-sky treaties and strategic alliances<sup>10</sup> turn the market for air transport into a global one tending to further boost competition within the European Union? And who is going to orchestrate a policy of selective growth and shrinkage under these circumstances?

With so many queries, one can hardly expect to find a simple recipe. One could try cooperation and coordination instead of competition as advocated in the case of seaports (Drewe and Janssen, 1996). Complementarity is a key factor in cooperation. Complementarities can be translated into opportunities for selective growth and shrinkage of airports in the European Union, taking into account both the development of logistic potentials and the management of social costs (as outlined in sections 3 and 4 respectively). The example of distribution centers points at a hierarchical positioning. Under the influence of logistic developments, a new hierarchy of distribution centers is expected to emerge (table 6). How about airports? Will the Trans-European Airport Network show the way, the new typology shown in figure 2 (section 2) or a US-style hub & spoke network?

A simple listing of Community connecting points, regional connecting points and accessibility points does not say much about complementarities. Moreover, will there be room at the top for 40 airports in the EU? The new typology is basically volume-oriented (size of domestic market) and supply-oriented (continental and intercontinental origins and destinations). It also includes hub dominance. However, as we said before, searching for an optimal situation, economic development and living environment too need to be accounted for.

In the US, deregulation and subsequent mergers and take-overs have resulted in six large airlines spread over 32 hubs, functioning as turntables and being fed by smaller airplanes and/or lower frequencies from the spokes.

Each main carrier minimally operates from 3 to 4 hubs and a maximum of 8 hubs whereas the most attractive hubs normally have only one main carrier. Hubbing has a number of advantages such as better transit opportunities, higher frequencies and lower costs. But there are also (inherent) disadvantages as a higher handling capacity is required and airplane and fleet productivity are low because of longer waiting times. Moreover, the US market of air transport differs from the European market in more than one respect: market size and composition, distances and densities, transport alternatives such as rail transport. Hubbing in Europe will also meet with congestion partly caused by inefficiencies of air control.

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<sup>10</sup> Take, for example, the so-called Star Alliance in which Lufthansa (for the time being) joins hands with Air Canada, SAS, United Airlines and Varig.

**Table 6. A new hierarchy of distribution centers**

TYPE OF NODE	CHARACTERISTICS
<b>INTERNATIONAL MAIN LOGISTIC CENTER (MAINPORT)</b>	<ul style="list-style-type: none"> <li>• Located at main economic development and transport axes</li> <li>• directly linked to intercontinental flows</li> <li>• technically advanced combined loading/unloading facilities for road and rail</li> <li>• intermodal facilities for road/rail and water transport</li> <li>• sophisticated information exchange facilities (EDI)</li> <li>• capacity and space to handle/store large quantities of different types of goods for different customers to different quality levels</li> <li>• availability of vacant space for logistic platforms of all different kinds of logistic/producer services</li> </ul>
<b>INTERNATIONAL LOGISTIC CENTER</b>	<ul style="list-style-type: none"> <li>• located directly at main European transport axes</li> <li>• active on various international networks and flows</li> <li>• functions as logistic platform for consolidation/de-consolidation of nearly all types of products</li> <li>• various logistic and producer services</li> <li>• dominant mode is truck, but also accessible by rail and combined rail/road transport</li> </ul>
<b>INTERNATIONAL TRANSPORT &amp; DISTRIBUTION CENTER</b>	<ul style="list-style-type: none"> <li>• located at important international transport axes to and from the mainports</li> <li>• function primarily as favored locations for transfer, transshipment, storage and/or distribution activities of international operating carriers and shippers</li> <li>• dominant mode is truck. Many are also linked by another mode of transport, rail or water</li> </ul>
<b>REGIONAL TRANSPORT &amp; DISTRIBUTION CENTER</b>	<ul style="list-style-type: none"> <li>• located at junctions and other platforms in infrastructural networks and/or platforms for the distribution of goods within about 50 Km.</li> <li>• predominant location factor is size of the market (population), degree of competition for space</li> <li>• spatial cluster of transport companies</li> </ul>

Source: Drewe and Janssen, 1996.

Complementary cooperation and a suiting new hierarchy of airports in Europe require a concerted action of the numerous shareholders: airports, airlines, national and regional authorities, business firms, etc. They also require new guidelines for the Trans-European Airport Network (plus a more efficient Eurocontrol). By the way, back in 1993, the European Commission has doubted whether a hub-and-spokes approach will contribute to the overall efficiency of the Community network in the long run: "Special attention should thus be given to measures aimed at easing the pressure on the large airports and favouring a geographical distribution of air transport services for both current and future demand" (European Commission, 1993, 8). For a more detailed analysis of European airline networks see Caves (1997), distinguishing the central areas of Europe ("hinterland" hubs, alternative hubs at secondary airports in the same metropolitan area, by-pass hubbing points in provincial cities) from peripheral regions in the EU ("gateway" hubs or "hourglass" hubs).

The airport of the future is part of an uncertain world. Are we heading for the global village, global recession or greening of business? Whatever looms ahead, a strategy of complimentary cooperation provides a way to reduce uncertainty. So does R&D. They may go a long way towards reducing uncertainty, but unlikely the whole way. So one also needs

to accept uncertainty to some extent resorting to an intelligent phasing of the implementation of plans. Why not try a strategy of selective growth and shrinkage? It is preferable to a risky laissez-faire and to the "simple, easy to convey, wrong solution".

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**Estimating the Bias Resulting from the Use of Conventional Mode Choice  
Models**

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# 1 INTRODUCTION

With the advent of new major policy issues concerning intercity freight and passenger transportation, such as intermodal competition, deregulation, introduction of new modes and/or technologies, researchers have been increasingly dissatisfied with the application and performance of conventional mode choice models. Perhaps the most critical drawback in the application of these models in the area of intercity freight transportation has been the inability of modelling decisions in a simultaneous rather than sequential matter. It is widely accepted that decision-makers, for example shippers, make their choices of mode, shipment size, frequency, and supply market simultaneously, not in sequence. Therefore, demand models that deal with only one of these choices, for example, the choice of mode, represent only one part of the complete model. These models are suspected to produce inaccurate or "biased" results. Consequently, a number of researchers have developed alternative models to overcome this weakness, see for example, Kim (1984), McFadden, Winston and Boersch-Supan (1985), Kim (1987), and Abdelwahab and Sargious (1992).

This paper provides quantitative evidence on the amount and significance of this "bias," by comparing a biased and a bias-free version of the same mode choice model calibrated from the same data set. The biased model is represented by a conventional probit mode choice model, whereas the bias-free model is represented by a simultaneous discrete/continuous model for the joint choice of mode and shipment size. The paper will mainly focus on the effects of simultaneity on the values and significance of the parameter estimates of conventional mode choice models, and on the magnitude of the own and cross elasticities of mode choice probabilities with respect to freight charges. The latter effects should provide an insight into the amount of bias in the degree of intermodal competition estimated in studies employing conventional mode choice models.

## 2 METHODOLOGY

The proposed methodology of estimating the bias in the parameter estimates and the various econometrics measures of conventional mode choice models is a straightforward one. It can be summarized as follows: 1) a conventional mode choice model is specified and calibrated; 2) using the same data base, a simultaneous mode/shipment size choice model is specified and calibrated; 3) results obtained from steps 1 and 2 are compared.

The basic structure of the conventional probit mode choice model (the biased model) is given as:

$$I_i^* = Z_i\alpha - \zeta_i \quad (1)$$

whereas the basic structure of the simultaneous mode/shipment size choice model (the bias-free model) is given as (further details can be found in Abdelwahab and Sargious, 1992):

$$I_i^* = X_i\gamma + Y_{1i}\eta_1 + Y_{2i}\eta_2 - \epsilon_i \quad (2)$$

$$\text{Truck: } Y_{1i} = X_{1i}\beta_1 + \epsilon_{1i} \quad \text{iff } I_i^* > 0 \quad (3)$$

$$\text{Rail: } Y_{2i} = X_{2i}\beta_2 + \epsilon_{2i} \quad \text{iff } I_i^* \leq 0 \quad (4)$$

where:

$I_i^*$  = unobserved index which determines the mode choice,

$Y_{1i}, Y_{2i}$  = endogenous dependent variables (e.g., shipment size by truck and rail, respectively),

$Z_i, X_i, X_{1i}, X_{2i}$  = vectors of exogenous independent variables (e.g., commodity, market and modal attributes),

$\alpha, \beta_1, \beta_2, \gamma, \eta_1, \eta_2$  = vectors of estimable parameters, and,

$\zeta_i, \epsilon_i, \epsilon_{1i}, \epsilon_{2i}$  = residual terms.

To allow for the simultaneity of decision-making regarding the choices of mode and shipment size, the residuals  $\epsilon_i, \epsilon_{1i}$ , and  $\epsilon_{2i}$  are assumed to be serially independent and have a trivariate normal distribution with mean vector  $\mathbf{0}$  and non-singular covariance matrix  $\Sigma$ ,

$$\Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{1\epsilon} \\ \sigma_{21} & \sigma_2^2 & \sigma_{2\epsilon} \\ \sigma_{\epsilon 1} & \sigma_{\epsilon 2} & \sigma_\epsilon^2 \end{bmatrix}$$

The covariances of interest here are  $\sigma_{1\epsilon}$  and  $\sigma_{2\epsilon}$ , representing the interdependence between the mode choice and the truck and rail shipment size choices, respectively.

Equation 2 (the mode choice model) was specified as a binary probit model, and Equations 3 and 4 were specified as linear regression equations. Due to their covariance structure, the three equations must be estimated as a "system of simultaneous equations". The alternative model (Equation 1) is simply a conventional probit mode choice model which is given by the reduced form of Equation 2, except that it is estimated as a binary probit model independent of the shippers' choices of shipment size. Details of the simultaneous model specification and estimation process is available in Abdelwahab and Sargious (1992). Because Abdelwahab and Sargious (1992) did not estimate the conventional mode choice model as part of their study, and to allow for comparison of results obtained by the two models, it was estimated here using the same data set. Both the simultaneous and conventional models are estimated using the maximum likelihood (ML) method.

The following tests are used to aid in the examination of the simultaneity bias of conventional mode choice models:

**Test 1:** Statistical significance of the covariance terms,  $\sigma_{1\epsilon}$  and  $\sigma_{2\epsilon}$ , which represent the correlation coefficients between the mode choice equation and the two shipment size equations,

**Test 2:** Comparison of the value and significance of the parameter estimates of the two models,

**Test 3:** Comparison of the predictive ability of the two models, and

**Test 4:** Comparison of the own and cross price elasticities of mode choice probabilities of the two models.

As indicated earlier, the covariance terms,  $\sigma_{1\epsilon}$  and  $\sigma_{2\epsilon}$ , are estimated using a multi-equation ML method (Test 1). The predictive ability of the models can be judged by each model's coefficient of determination and by applying the two models to predict the modal shares in various market segments (Test 3).

The first three tests can be used to examine the *direct* effects of simultaneity. However, a less apparent effect of simultaneity can be detected by examining the own and cross price elasticities of the mode choice probabilities (Test 4). It is these *indirect* effects that can produce biases in many econometric measures, and are therefore, discussed in more details in this study.

A *disaggregate* elasticity of mode choice probabilities represents the responsiveness of a shipper's choice probability to a change in the value of some attribute. The *direct* or *own* elasticity is defined as the responsiveness of a shipper's probability of choosing some mode to a change in the value of some of the same mode's attribute. In the case of the probit model, this elasticity is given by (e.g., see Ben-Akiva and Lerman, 1987):

$$E_{x_{ik}}^{P_{ni}} = \frac{\partial P_{ni}}{\partial x_{ik}} \cdot \frac{x_{ik}}{P_{ni}} \quad (5)$$

where:

- $E_{x_{ik}}^{P_{ni}}$  = the own elasticity of mode choice probability,  $P_{ni}$ , with respect to a modal attribute,  $x_{ik}$ ,
- $P_{ni}$  = the probability of individual  $n$  choosing mode  $i$ , and,
- $x_{ik}$  = the  $k$ -th attribute of mode  $i$ .

Given the formulation of the probit model, the elasticity of  $P_{ni}$  with respect to  $x_{ik}$  can be written as:

$$\begin{aligned} E_{x_{ik}}^{P_{ni}} &= \frac{\partial}{\partial x_{ik}} (\Phi(V_i - V_j)) \cdot \frac{x_{ik}}{\Phi(V_i - V_j)} \\ &= \pi_k x_{ik} \frac{\phi(V_i - V_j)}{\Phi(V_i - V_j)} \end{aligned} \quad (6)$$

where:

- $V_i, V_j$  = the systematic components of the utility functions associated with modes  $i$  and  $j$ , respectively,
- $\pi_k$  = the parameter estimate of  $x_{ik}$  in the reduced-form probit mode choice model, and
- $\Phi, \phi$  = the normal cumulative and probability density functions, respectively.

Similarly, the disaggregate *cross* elasticity represents the responsiveness of a shipper's probability of choosing mode  $i$  to a change in the value of some of mode  $j$ 's attributes (e.g.,  $x_{jk}$ ). In the case of the binary probit, since the probability  $P_{ni} = \Phi(V_i - V_j)$ , and  $P_{nj} = 1 - P_{ni}$ , the cross elasticity is simply given as:

$$E_{x_{jk}}^{P_{ni}} = \frac{\partial P_{ni}}{\partial x_{jk}} \cdot \frac{x_{jk}}{P_{ni}} = -\pi_k x_{jk} \frac{\phi(V_i - V_j)}{\Phi(V_i - V_j)} \quad (7)$$

From these derivations, the aggregate own and cross elasticities of mode choice probabilities (Test 4) are given by (Abdelwahab, 1996):

$$E_{x_{ik}}^{\hat{P}_{ni}} = \frac{\pi_k \sum_n x_{ik} \phi(V_i - V_j)}{\sum_n \Phi(V_i - V_j)}, \quad E_{x_{jk}}^{\hat{P}_{ni}} = \frac{-\pi_k \sum_n x_{jk} \phi(V_i - V_j)}{\sum_n \Phi(V_i - V_j)} \quad (8)$$

where:

$$\begin{aligned} E_{x_{ik}}^{\hat{P}_{ni}}, E_{x_{jk}}^{\hat{P}_{ni}} &= \text{the aggregate own and cross elasticities of mode choice} \\ &\quad \text{probabilities, and} \\ \hat{P}_{ni} &= \text{the expected share of mode } i \text{ calculated as the average} \\ &\quad \text{of all individual probabilities } P_{ni}. \end{aligned}$$

### 3 RESULTS

As discussed in Section 2, the magnitude and significance of simultaneity bias is examined by four tests. The results of these tests are presented and discussed below.

#### Test 1: Covariances $\sigma_{1\epsilon}$ , $\sigma_{2\epsilon}$ .

From the specification of the simultaneous model (Equations 2-4) and its covariance structure,  $\Sigma$ , the covariance parameters  $\sigma_{1\epsilon}$  and  $\sigma_{2\epsilon}$  are defined to represent the interaction (i.e., correlation) parameters between the mode choice equation and the truck and rail shipment size equations, respectively. Equations 2-4 were estimated simultaneously by the maximum likelihood (ML) method. The ML produces an estimate for each parameter specified in each of the 3 equations, as well as estimates of  $\sigma_{1\epsilon}$  and  $\sigma_{2\epsilon}$ . The ML estimates of  $\sigma_{1\epsilon}$  was  $-0.1936$  ( $t = -1.65$ ), and that of  $\sigma_{2\epsilon}$  was  $0.4868$  ( $t = 2.66$ ). The estimated value of  $\sigma_{1\epsilon}$  suggests a large and significant interdependence between the error terms of the mode choice equation,  $\sigma_\epsilon$ , and that of the truck shipment size equation,  $\sigma_1$ . Although this parameter is significant at only the 10% level, it does serve to show the presence of a *negative* selection bias between the choices of truck and shipment size when the two choices are modeled separately. On the other hand, the parameter estimates of  $\sigma_{2\epsilon}$  indicates a significant *positive* selection bias between the choices of rail and shipment size when the two choices are modeled independently.

The significance of the parameter estimates of  $\sigma_{1\epsilon}$  and  $\sigma_{2\epsilon}$  suggest that not only shippers make their choices of mode and shipment size simultaneously, but they tend to adjust

their choices to maximize their utilities (e.g., minimize their shipping costs). As noted by Abdelwahab and Sargious (1991), shippers with no predetermined shipment size may change their choices of shipment size and frequency of shipment to minimize their total shipping and inventory costs. As evident from the negative value of  $\sigma_{1\epsilon}$  and the positive value of  $\sigma_{2\epsilon}$ , shippers tend to decrease the sizes of their shipments when considering shipping by truck ( $\sigma_{1\epsilon} < 0$ ), whereas they tend to increase the sizes of their shipments when considering shipping by rail ( $\sigma_{2\epsilon} > 0$ ). These observations seem to be consistent with the rate structure of the various modes, and the rate setting policy in the industry<sup>1</sup>.

### Test 2: Parameter estimates of the two models.

In an attempt to estimate the effects of simultaneity on the parameter estimates of the conventional mode choice model, each of the mode choice and shipment size equations were estimated independently<sup>2</sup>. The mode choice model was estimated by single-equation ML, and the shipment size equations were estimated by ordinary least squares (OLS). Each equation was reestimated with the same specification in order to avoid any changes in the parameter estimates due to misspecification.

The reestimation process resulted in very little change to the values of the parameter estimates of the mode choice/shipment size model. None of the independent variables changed its sign as a result of the reestimation process. However, because the ML is more efficient than the OLS, all the parameter estimates had smaller standard errors, and therefore, higher "t" values.

### Test 3: Predictive ability of the two models

The previous two tests dealt with the presence of simultaneity bias and its effect on the values (i.e., magnitude and sign) of the estimated parameters. To examine the simultaneity effects on the performance of the model, it is necessary to compare the two models using some measure of predictive ability.

In terms of the coefficient of determination, results obtained by both estimation methods (i.e., as a single-equation conventional model, and as a multi-equation simultaneous model) showed almost identical values. It is therefore expected that both versions of the mode choice model would predict the modal shares in the various market segments with similar accuracy. A total of 25 market segments were identified based on

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<sup>1</sup>It is recognized that shippers can be tempted to adjust (up or down) their shipment size in order to make use of certain "discounts" that may be offered by carriers as a result of intra or inter-modal competition. For further details on freight rate structures and their relationships to shipment size, see Abdelwahab and Sargious (1991).

<sup>2</sup>The main emphasis in this paper will be on the simultaneity effects on the parameter estimates of the mode choice model.

commodity group and geographic area<sup>3</sup>, and the two models were applied to predict the modal share in each segment. The performance of the two models is summarized in Table 1. As can be seen from Table 1, there seems to be very little difference in the predictive abilities of the simultaneous mode choice/shipment size model and the conventional mode choice model.

#### Test 4: Elasticities of mode choice probabilities

Perhaps a more significant and less apparent effect of simultaneity can be revealed by examining the values of elasticities of mode choice probabilities obtained by the two models. Because conventional mode choice models fail to account for the indirect effects of level of service attributes on mode choice, these models are expected to overestimate the responsiveness of shippers' choices of mode to changes in modal or commodity attribute(s). This result follows from the fact that in reality shippers tend to adjust not only their modal choice, but also their choice of shipment size in response to a change in some modal and/or commodity attribute. These adjustments are usually made in order to make use of modal advantages which are available only in certain weight brackets. For example, truck service may be a better choice (i.e., faster, less expensive, etc.) than rail for moving relatively small shipments. Therefore, if the truck freight charges increase such that the movement of a certain shipment by truck becomes less *competitive* given its weight, the shipper may choose to reduce his shipment size (and increase shipment frequency) rather than switch to rail.

An empirical investigation of the above argument can be carried out by examining the values of aggregate elasticities of mode choice probabilities as calculated by a conventional mode choice model, and by a simultaneous mode choice/shipment size model. Results of this comparison are summarized in Table 2.

As expected, the elasticities of both truck and rail choice probabilities are overestimated by the conventional mode choice model relative to the mode choice/shipment size model. However, the magnitude of this overestimation seems to be relatively small, ranging from 3.7% to 9.4% in the case of truck, and from 4.3% to 9.6% in the case of rail elasticities. The overestimation of elasticities should be examined within the context of the specific application because a small difference in the value of an elasticity could translate into a large difference in the value being calculated. For example, using the conventional mode choice model a 10% increase in rail freight charges in the movement of textile and apparel products (CG II) in the Official I.C.C. territory will result in a 16.7% reduction in rail's share of the total traffic in this market. On the other hand, using the joint mode choice/shipment size model, the same reduction in rail's share of traffic is estimated at 15.2%, a difference of 9.6% from the first estimate. Therefore, if these elasticities were to be used by the railroads to estimate the impacts of a certain rate-setting policy, the difference in the results of the two models could be large enough

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<sup>3</sup>See Abdelwahab and Sargious (1992) for description of the various market segments.

to warrant the implementation or abandonment of such a policy.

Also shown in Table 2 are the cross price elasticities of mode choice probabilities. It is noted that, in general, the amount of overestimation in the cross price elasticities is larger than that in the case of own price elasticities. The cross price elasticities reflect the degree of intermodal competition represented in the sensitivity of choosing one mode to a change in the freight charges of the competing mode. Therefore, conventional mode choice models seem to overestimate the degree of competition between truck and rail<sup>4</sup>.

## 4 SUMMARY AND CONCLUSIONS

There seems to be significant evidence that decisions regarding mode and shipment size (and, therefore, shipment frequency) are made simultaneously. This is clear from the statistical significance of the covariance terms estimated in the joint mode choice/shipment size model (Test 1). It can also be concluded that results obtained from conventional mode choice models are biased even when their "goodness of fit" measures are acceptable. In spite of the statistical significance of the simultaneity effects observed in conventional mode choice models, very little negative impact was observed on the predictive ability of these models. The insignificant effects of simultaneity on the predictive ability of conventional mode choice models was demonstrated by Tests 2 and 3.

In terms of the effects of simultaneity on the price elasticities of mode choice probabilities, results showed that conventional models consistently overestimate both the own and cross elasticities of mode choice probabilities with respect to freight charges. The amount of bias, expressed in percentage difference in the elasticities obtained from the two models, varied from 3.7% to 17.7%, depending on the commodity group and geographic area under consideration.

From the above conclusions, it can be argued that much of the concern over the use of conventional mode choice models in freight and passenger transportation may have been overstated. Specifically, when conventional mode choice models are used for the purposes of predicting modal shares, they can be expected to produce accurate results. However, when the same models are used to estimate the sensitivities of mode choice decisions, or the degree of intermodal competition, they produce biased results.

Further work is needed before a general statement can be made regarding the validity of results obtained by studies utilizing conventional mode choice models. Results

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<sup>4</sup>It should be noted that the truck mode in this study included both truckload (TL) and less-than-truckload (LTL) shipments. Therefore, it can be expected that the competition between truck and rail is higher in the movement of TL shipments. That is, conventional mode choice models can be expected to produce more accurate results when applied to study the TL/rail market, as opposed to the truck/rail market.

obtained in this study are derived from analysis of the intercity transportation of manufactured goods in the U.S. Caution should be exercised when extending the results to freight markets with different structure or competitive environment. Finally, to enhance the applicability of simultaneous choice models to the freight transportation industry, further research on the feasibility of extending these models to include other decisions (e.g., shipment frequency, supply market, etc) and modes (i.e., the use of multinomial rather than binary models) is needed.

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Table 1: Effects of simultaneity bias on the predictive ability of the mode choice model

Prediction Accuracy ( $\pm$ )	Number of market segments	
	Simultaneous Mode Choice Model	Conventional Mode Choice Model
1%	2	2
5%	11	10
10%	8	7
20%	4	6
Total	25	25

Table 2: Effects of simultaneity bias on the elasticities of mode choice probabilities

CG†	Interstate Commerce Commission (I.C.C.) Territory‡	Aggregate Elasticity of Mode Choice Probability					
		Truck			Rail		
		Conven- tional Model	Present Model	% Diff.	Conven- tional Model	Present Model	% Diff.
I	O	-1.1108	-1.0305	7.8	-1.5327	-1.4159	8.2
	S	-1.6500	-1.5326	7.7	-1.8676	-1.7249	8.3
	W	-1.2949	-1.2086	7.1	-1.8108	-1.6836	7.6
	SW	-2.2498	-2.1687	3.7	-2.6156	-2.5068	4.3
	M-P	-0.9176	-0.8601	6.7	-1.2498	-1.1612	7.6
II	O	-1.3659	-1.2489	9.4	-1.6671	-1.5217	9.6
III	O	-0.7377	-0.6848	7.7	-0.9771	-0.9001	8.6
	S	-1.5033	-1.4051	7.0	-1.6786	-1.5568	7.8
	W	-1.3373	-1.2687	5.4	-1.7687	-1.6617	6.4
	SW	-1.6259	-1.5554	4.5	-1.8639	-1.7713	5.2
	M-P	-0.8422	-0.7786	8.2	-1.3183	-1.2090	9.0
IV	O	-1.1809	-1.0857	8.8	-1.4106	-1.2928	9.1
V	O	-0.6640	-0.6137	8.2	-0.8987	-0.8240	9.1
	S	-1.2399	-1.1595	6.9	-1.4463	-1.3401	7.9
	W	-0.9506	-0.8830	7.7	-1.3250	-1.2203	8.6
	SW	-2.2237	-2.1199	4.9	-2.8799	-2.7249	5.7
	M-P	-1.4289	-1.3578	5.2	-1.9083	-1.8073	5.6
VI	O	-1.1831	-1.1024	7.3	-1.3504	-1.2518	7.9
	S	-2.6371	-2.5058	5.2	-2.5666	-2.4218	6.0
	W	-1.9072	-1.8162	5.0	-2.1801	-2.0611	5.8
VII	O	-0.7063	-0.6553	7.8	-1.0133	-0.9342	8.5
VIII	O	-1.0725	-0.9934	8.0	-1.4247	-1.3129	8.5
	S	-1.6854	-1.5725	7.2	-1.9318	-1.7886	8.0
	W	-1.3802	-1.2806	7.8	-1.8403	-1.6992	8.3
	M-P	-1.7073	-1.6005	6.7	-2.2880	-2.1274	7.5

†Commodity Group as listed in Table 3.

‡Note: models were estimated at the individual standard metropolitan statistical area level. O = Official; S = Southern; W = Western; SW = Southwestern; M-P = Mountain-Pacific.

Table 2—Continued: Effects of simultaneity bias on the elasticities of mode choice probabilities

CG†	Interstate Commerce Commission (I.C.C.) Territory‡	Aggregate Elasticity of Mode Choice Probability					
		Truck-Rail			Rail-Truck		
		Conven- tional Model	Present Model	% Diff.	Conven- tional Model	Present Model	% Diff.
I	O	1.2317	1.0997	12.0	1.4370	1.3269	8.3
	S	1.7631	1.6355	7.8	1.7829	1.6164	10.3
	W	1.4264	1.2897	10.6	1.7781	1.5777	12.7
	SW	2.4537	2.3142	6.0	2.5323	2.3491	7.8
	M-P	0.9894	0.9178	7.8	1.1926	1.0881	9.6
II	O	1.4540	1.3327	9.1	1.6071	1.4260	12.7
III	O	0.8370	0.7308	14.5	0.9535	0.8435	13.0
	S	1.6718	1.4994	11.5	1.7103	1.4589	17.2
	W	1.5203	1.3538	12.3	1.8055	1.5572	15.9
	SW	1.7527	1.6598	5.6	1.8010	1.6599	8.5
	M-P	0.9521	0.8308	14.6	1.2735	1.1330	12.4
IV	O	1.2930	1.1586	11.6	1.3908	1.2115	14.8
V	O	0.7685	0.6549	17.3	0.8903	0.7722	15.3
	S	1.4057	1.2374	13.6	1.4584	1.2558	16.1
	W	1.0361	0.9423	10.0	1.3026	1.1436	13.9
	SW	2.5222	2.2622	11.5	2.8651	2.5536	12.2
	M-P	1.5693	1.4490	8.3	1.8707	1.6937	10.5
VI	O	1.2811	1.1764	8.9	1.2973	1.1731	10.6
	S	3.0136	2.6740	12.7	2.5237	2.2695	11.2
	W	2.1648	1.9381	11.7	2.1990	1.9315	13.9
VII	O	0.7895	0.6993	12.9	1.0085	0.8754	15.2
VIII	O	1.1757	1.0601	10.9	1.3521	1.2303	9.9
	S	1.8358	1.6781	9.4	1.8471	1.6761	10.2
	W	1.5400	1.3665	12.7	1.7639	1.5924	10.8
	M-P	1.8420	1.7080	7.8	2.2089	1.9936	10.8

†Commodity Group as listed in Table 3.

‡O = Official; S = Southern; W = Western; SW = Southwestern; M-P = Mountain-Pacific.

Table 3: Commodity groups in the manufactured freight sector.

Commodity Group	2-digit STCC <sup>§</sup>	Industry Description
I	20	Food and kindred products
	21	Tobacco products
II	22	Textile mill products
	23	Apparel and other finished textile products
III	28	Chemicals and allied products
	29	Petroleum and coal
IV	30	Rubber and miscellaneous plastic products
	31	Leather and leather products
V	33	Primary metal products
	34	Fabricated metal products
VI	36	Electrical machinery, equipment, and supplies
	37	Transportation equipment
VII	32	Stone, clay, glass and concrete products
VIII	24	Lumber and wood products (except furniture)
	25	Furniture and fixtures
	26	Pulp, paper, and allied products

§ STCC is the Standard Transportation Commodity Code. Note: models were estimated at the 5-digit STCC (individual commodity) level.

