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Research

COST 318

Interactions between High-Speed Rail and Air Passenger Transport

Final Report

European Commission
Directorate General Transport

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EXECUTIVE SUMMARY

With the inauguration of the first High-Speed Railway in Europe (1981) between Paris and Lyon a strong influence on Air Passenger Transport was observed. This influence has advantages and effects on both systems. So the proposal for an investigation of these two high speed systems was adopted for COST research topics. The working programme was elaborated by a Subcommittee and is summarised in six theses and nine hypotheses that formed the base for carrying out COST Action 318. The participating countries Belgium, France, Germany, Ireland, Italy, the Netherlands, Portugal, Slovenia, Spain, Sweden and Switzerland have signed the COST Action 318 which started in March 1994.

Several countries are on the way to build up an Europe-wide high-speed railway system: Estimatedly by about the year 2015, 30.000 km high-speed rail lines will have been built in Europe, of which 19.000 km high-speed tracks and 11.000 km line improvements for speeds from 160 to 250 km per hour. According to an updated forecast for Europe issued by IATA, growth-rates in air transport are expected to be even higher in the future than in the past. Between 1990 and 1992 passenger boarding declined due to the world-wide economic recession but again annual growth was higher than 4% for the next period in Europe. In fact, air traffic slumps in the past 20 years were rapidly matched the following years and not affecting the general upward trend. As a consequence, disturbing (and costly) capacity constraints are likely to increase.

The main objective of the COST Action is to identify and analyse the interactions and complementarities between high-speed rail (HSR) and air passenger transport, (APT), and to stress the benefit which arises from these combined actions for users and public welfare.

The introductory chapter of this report shows the development of rail and air transport, discusses the question if APT is a forerunner and a model for HSR, describes the idea of HSR in Europe and asks if HSR's development is limited in the future.

The second chapter deals with problems of optimising the adjustment between supply and demand, in particular the ability of HSR to compete with APT, the possibility of co-ordination of rail and air transport systems capacities due to HSR, the improvement in the distribution of air transport demand among airports and discusses scenarios of complementarity between air and high-speed rail passenger transport.

Chapter three discusses the increase of socio-economic profitability by new High Speed Systems (HSS), especially the questions of the need for extended services on trains, and of multidimensional effects of HSR, and the question if air transport is more flexible than HSR and if air transport allows the saving of important investment costs compared to HSR.

The fourth chapter describes the general and multidimensional effects of rail stations at airports, the distribution of air transport demand among airports due to these rail stations and their impact on the public transport balance accounts.

Chapter five gives a comprehensive description of the results which in certain cases leads to a reformulation of the hypotheses.

As a general result can be emphasised that the area of influence of rail and air transport will alter significantly if HSR is realised for all connections with high traffic load: best effects result if both HSR and APT-networks are connected by efficient railway stations at all important airports.

While for travel distances of more than 300 km the competitive edge of conventional railways is rapidly declining, for HSR this only applies for travel distances of over 600-700 km. In a future with HSR, APT will predominate on longer travel distance relations.

A consequence of this shift in the area of influence is, that air traffic will be reduced for certain relations by up to 50% if HSR connections provide an outstanding alternative. But also with a fully accomplished HSR network in Europe of about 30.000 km the medium air transport reduction in the rail/air modal split will probably not exceed 15-20%.

There are also important effects on the reduction of environmental damage (especially on air quality and reduction of congestion at airports).

The consequence of all these modifications is a new and more sustainable balance of long distance trip distribution between rail and air transport and also for road traffic.

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List of Abbreviations

ACI	Airports Council International
ADAC	Allgemeiner Deutscher Automobil Club, German Motorclub
AdP	Aéroports de Paris, Authority of Paris Airports
ADV	Arbeitsgemeinschaft Deutscher Verkehrsflughäfen (Association of the German Airports)
AEA	Association of European Airlines
APT	Air Passenger Transport
ATC	Air Traffic Control
AVE	High-Speed Train of Spain
BA	British Airways
BAA	British Airways Authorities
BATC	Brussels Air Terminal Company
BLO	Bologna Airport
BMV	Bundesministerium für Verkehr (German Ministry of Transport)
BR	British Rail
BRU	Brussels Airport
CDG	Paris - Charles de Gaulle Airport
CDG 2	Paris - Charles de Gaulle Airport Terminal 2
CIA	Rome secondary Airport (Ciampino)
DIRETTISSIMA	High-Speed Line of Italy between Rome and Florence
DVWG	Deutsche Verkehrswissenschaftliche Gesellschaft, German Society of Transport-Science
ETR	High-Speed Train of Italy
EU/EC	European Union/ European Commission
FCO	Rome Airport (Fiumicino)
FLR	Florence Airport
FRA	Frankfurt-Main Airport
GNP	Gross National Product
GNSS	Global Navigation Satelite System
GVA	Geneva Airport
HCG	Dutch Office
Heathrow	London Airport (in the West of the agglomeration)
HSR	High-Speed Rail
HSS	High-Speed System
IATA	International Air Transport Association
IC	InterCity
ICAO	International Civil Aviation Organisation

ICE	High-Speed Train of Germany
IEE	Inventorisation Economic Effects (Dutch Study)
ILS	Instrument Landing system
INRETS	Institut national de recherche sur les transports et leur sécurité (France)
IT	Information Technology
ITA	Institut du Transport Aérien, Paris
Linate	Milan Airport (close to city)
MLS	Microwave Landing System
MXP	Milan (hub-) Airport Malpensa (for the time to come)
O-D	Origin-Destination
ORY	Paris-Orly Airport
PASO	Plan van Aanpak Shipol en Omgeving (Dutch Study)
P/LBKA	Line Paris/London - Brussels - Cologne - Amsterdam
PM	Materials similar like soot
PSA	Pisa Airport
RATP	Urban Transport Company of Paris
RER	Express Metro of Paris Region
Roissy	Paris-CDG Airport
Schiphol	Amsterdam Airport
Stansted	London Airport (in the North-East of the agglomeration)
STR	Stuttgart Airport
STOL	Short Take-Off and Landing
TAV	Treni ad Alta Velocità (Future high-speed line Rome-Florence-Milan)
TEE	Trans Europe Express
TGV	Train à Grande Vitesse (High-Speed Train of France)
X 2000	High-Speed Train of Sweden
ZRH	Zurich Airport
[1]; [2] etc.	Reference to the Bibliography

1. INTRODUCTION AND PRELIMINARY TOPICS

With the inauguration of the first high-speed railway (HSR) in Europe (1981) between Paris and Lyon a strong influence to air passenger transport (APT) was observed. This influence will have advantages and effects on both systems. So the proposal of an investigation on these two high-speed systems was adopted for COST research topics.

1.1 Recommendations of the Subcommittee

The official begin of COST Action 318 is March 1994.

The working programme was elaborated by a Subcommittee [1], which was founded in May 1990 and submitted its recommendations by the end of November 1991. The participating countries were Belgium, France, Germany, Ireland, Italy, The Netherlands, Portugal, Sweden and Switzerland[1].

The Subcommittee analysed and studied in detail the existing literature and knowledge in the field. In a Bibliography a set of important titles are mentioned (Annex 1) which were together with the discussions in the Subcommittee the base for the „state of the art" in HSR and air at this time (1991). In addition a special co-ordination took part with the ongoing study on complementarities between rail and air [2].

Finally the existent knowledge was summarised in six theses and the unsolved problems were enumerated in nine hypotheses. The investigations represented in these theses showed that there already exists much knowledge in this field. Among others the principle topics are:

- HSR transport can successfully compete with other transport modes, especially APT.
- In situations of low and medium transport demand APT has the best opportunities for further developments.
- HSR and APT can complement each other.
- Rail connections at airports can reduce external costs (safety, air pollution) and access costs.

But there is already a wide field for research as the hypotheses show (Annex 2). The work on these hypotheses (to accept or to reject) is the main topic of this report.

1 Spain and Slovenia joined the COST 318 programme at the beginning of the official task

Objectives and Definition of the Project:

Several countries are on the way to build up an Europe-wide high-speed railways system: Estimatedly by about 2015, 30.000 km will have been built in Europe, of which 19.000 km high-speed tracks and 11.000 km for speeds from 160 to 250 km per hour. But also growth-rates in APT are expected to be even higher than in the past: according to updated data for Europe issued by IATA. Between 1990 - 1995 passenger boarding declined due to the world-wide economic recessive but again annual growth is expected to 4% for the next period. In fact, air traffic slumps in the past 20 years were rapidly matched the following years and not affecting the general upward trend. As a consequence, disturbing (and costly) capacity constraints are likely to increase. Even if there is a relief from Europe's air flow management, it seems that by 2000 only few major (West-) European airports will not have reached their „limits of capacity".

The main objective of the project is to identify and analyse the interactions and complementarities between high-speed rail[2] (HSR) and air passenger transport (APT), and to stress the benefit which arises form these combined actions for the users and public welfare. The main fields of interest are:

Effects of HSR on APT

- Is the development of HSR limited in the future?
- Does HSR allow a better utilisation and co-ordination of rail and air capacities?
- Does HSR allow a better distribution transport demand among airport?
- What level of services is needed on HSR?
- Saving effects of HSR transport (time, transport and operation costs, energy etc.)

Reverse effects of APT on HSR

- Is APT a forerunner and a model for HSR?
- Is APT more flexible than HSR and does it allow the saving of important investment costs?

The effects of rail stations at airports on rail and air transport

- Do rail stations allow a better distribution of transport demand among airports?
- What is the impact of rail stations at airports on the public transport balance of accounts?

These questions demonstrate the wide field of research and investigations we have to deal with.

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2 High-speed rail is understood when the max. commercial speed is higher than 250 (200) km/h on new tracks and over 160 km/h to 250 (200) on improved tracks

1.2 Short historical description of the Development of Rail and Air Transport

The development of railways and HSR in Europe is a result of the evolution at the conventional railway. This is the reason why we treat the development of rail in this century just before high-speed emerged.

Before the First World War, railway traffic in Europe with high commercial speed had played only a relatively unimportant part. The main reasons for this were the bad relation between power and heavy constructed engines and the poor condition of the rail infrastructure for high-speed.

At the beginning of the century, the private railways were nationalised and changed into national railway companies because of its monopoly character in transportation and a difficult economic situation. This nationalisation resulted in the first possibility to transport passenger and goods at low and nationally guaranteed prices on a complete railway network.

1.2.1 Railways after the Second World War

After the Second World War Europe began to develop international long-distance connections. Because of the military damages, the infrastructure did not allow a higher speed, yet. The infrastructure was rebuilt slowly, but not as before. In 1945 the first international long-distance rail connection was rebuilt. In 1946, the first international East-West connection Copenhagen - Paris followed (with a feeder train to Berlin). The former luxury-train concept was not continued anymore by the railway companies, because they were more interested in gaining more quantitative and faster traffic.

In the 50s, the railways began building-up a new 200 km/h speed network which should have been a competitor to civil aviation[3]. In 1957, these long-distance traffic or *Trans-Express Trains* were brought into the concept *Trans-Europe-Express (TEE)* with a unified standard.

Trans-Europe-Express Concept

With the TEE-Concept the national railway companies tried to change the trend back from road and air to rail. The TEE-Concept contained a first-class comfort (like the luxury trains before the Second World War) and a commercial speed of more than 100 km/h and a top-speed of approximately 200km/h - the passport-control was always done in the train.

In 1975, the concept was improved by a permanent increasing supply, but it did not achieve the desired success in railway traffic. On one hand the attraction of flying was higher, because of the permanent improvements (e.g. the speed, frequencies, comfort and the supply of other services), and the road-traffic was becoming faster

3 The first high-speed train was the *Settebello* in 1952 which was operated between Milan and Florence with a max. speed of 200 km/h.

and cheaper than rail, on the other hand the *TEE*-Concept had not a real continuity in the schedule operation and improving equipment[4].

After the end of the *TEE*-Concept in the middle of the 70s national improved concepts with international destinations were developed. The first concept in this field was the Intercity-Concept in Germany, which was introduced in 1972 and extended permanently. The international destinations of the *TEE* were carried on as *EuroCity*. Other countries followed this *Intercity/EuroCity* concept and formed a new long-distance traffic-network in Europe which also has contained a 2-class-system and a typical design of each national railway company.

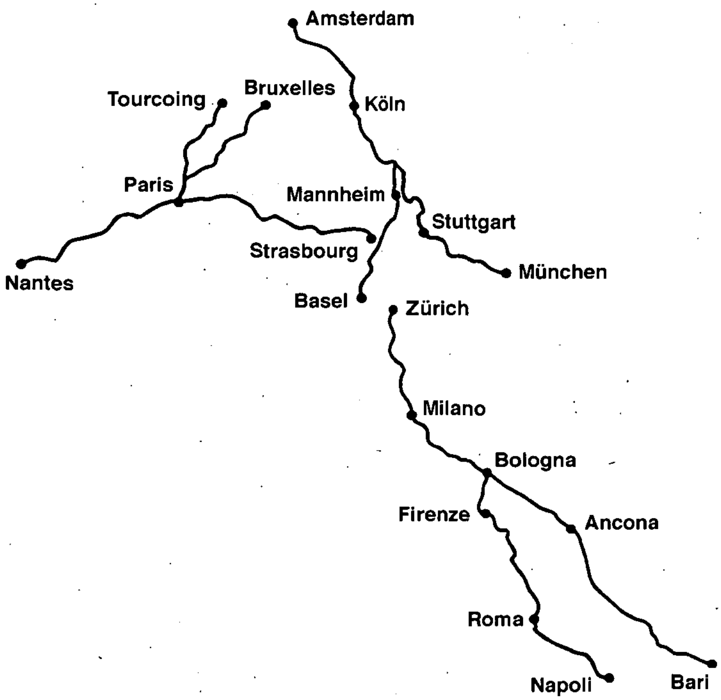

Figure 1: The TEE-Network during the last Schedule Period 1986/87

Shortly after the introduction of national long-distance trains 1981 the first real national high-speed project in Europe with a separate infrastructure began in France with the *Train à Grande Vitesse* (TGV) on a new built track between Paris and Lyon. The project was the beginning of the high-speed transport by rail in Europe.

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4 Only when the European night-trains of the Hotelzug AG (a German-Austrian-Swiss joint-venture) were introduced, the TEE-Concept with equal comfort was replaced. These trains have the big advantage against the civil aviation of a hotel-like service for passengers. But there is also a new concept by the airlines to offer similar services on air, but especially for long-distance flights.

1.2.2 Developments in aviation

The brothers Otto and Gustav Lilienthal succeeded in the first gliding flight in summer 1891 and the Wright brothers in the first motor flight in 1905. In 1909 Louis Blériot undertook the first „long distance" flight across the channel.

After the First World War, the pioneering time of international aviation started with air mail transport[5]. In August 1919, the International Air Traffic Association - a forerunner of the present IATA - was founded in The Hague. It had the task of co-ordination and representation of interests between the members and to the national institutions.

The most often operating types of aircraft were the Junkers JU F.13 (the first commercial aircraft), Fokker F-VII to the JU 52 and Douglas DC-2 and DC-3 before World War II. They were in general characterised by a small capacity of about 10-20 passengers, low speed, up to 250 km/h, and a short flying range. The aircraft were used in most cases by the upper classes only and the number of flights was limited.

Besides the conventional propeller driven aircraft, sea-plans[6] and airships[7] were able to offer a huge air passenger volume capacity with little „infrastructure" problems, but they were rather slow.

Aviation during and after Second World War

During the Second World War, the aviation e.g. the development of the airjets and the operation of big aircraft for military purposes (material transports and bombers) were forced strongly. Civil aviation and the work of a still small IATA almost ceased during that time.

Immediately after the Second World War a change happened in the use of aircraft and pilots. So, on one the hand jetplanes, on the other hand middle and large aircraft were used for the first time in civil aviation[8]. Furthermore navigation systems and air services were improved enormously thanks technical innovations during the war.

Development of modern civil aviation

Commercial aviation began its most important development in the 50s with the North Atlantic flights as the masterpiece (with technical stops in Shannon/Ireland and Gander/Newfoundland at the beginning, later non-stop). At first, national airlines began with national flights on longer distances (500 to 1000 km). So they only came

5 With famous names like Charles Lindbergh or with the Aéropostale, Antoine de Saint-Exupéry, and some former pilots of the First World War flying through the world: the first airmail link from Dakar to South America was flown by Jean Mermoz in May 1930 on a Latécoère sea-planes.

6 Seaplanes were mainly used because of the missing or insufficient landing opportunities.

7 The most famous example of airship was the Zeppelin from 1928 in the intercontinental service between Germany and America, until the explosion on the airship „Hindenburg „ in Lakhurst in May 1937. Thereafter the Zeppelinflights were reduced, later on cancelled, because of the German lack of helium as an alternative to the dangerous, explosive hydrogen.

8 So, e.g. the C-47 Dakotas were refurbished as DC-3s.

indirectly in competition with road and rail which concentrated their supply on short distances up to approximate 500 km and air traffic could increase by high rates. The first commercial jet aircraft used, the De Havilland D.H. 106 „Comet“, was introduced in 1952 on international flights but it had to be withdrawn after several accidents due to metal fatigue.

Through the still continuing progress in aviation technology at the end of he 50s and the first long-distance jets Boeing 707 and DC-8 were introduced at the beg (non-stop) intercontinental aviation began to expand. With the technical innovation and the increasing transport supply, competition pressure on the producers' market increased. Moreover still newer, bigger and more secure technical facilities were built and put into operations, in order to accelerate the flight dispatch.

In 1976, Air France and British Airways were authorised to operate the Concorde (100 seats) on a commercial base at twice the sound-speed, but over waters only. However, costs, high fares and load factors led to a network reduction of scheduled flights to the only destination of New York, still operating.

Trying to cope with aircraft overcapacities, the airlines offered cheaper, discounted fares. The airline traffic increased at a steady-growing rate of 5-10 % every year because of the purchasing power of passengers. This trend continued until the 90s. Besides the scheduled flights, the regional and the charter airlines developed[9] (see also chapter 1.6.3).

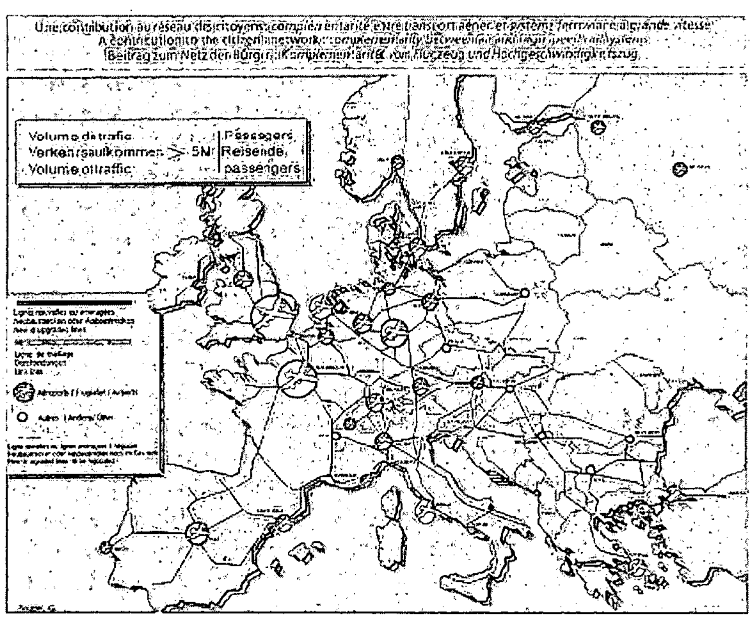

Figure 2: European Airports with more than 5 million Passengers (in the early 90s)

9 The charter flights have still an overaveraged increasing rate, although from a lower level on.

Beginning of regional aviation

As a „counter offensive“ from the air to the Trans-Europe-Express and because of the wide-spread success in America, the European regional air network developed. It allows flexible connections between regions and large airports (hubs) and resulted in a direct competition with rail [10]. Small turboprop aircraft with a seating capacity of about 18 to 50 places were used from the beginning. These aircraft have often a STOL (short take-off and landing capability) and are also economical in operation with a relative small passenger volume. In Great Britain, aircraft (e.g. Ae-146) for 100 passengers with STOL capability equal the propeller STOL performances[11].

1.3 Tendencies in the World around High-Speed Rail and Air Transport

1.3.1 Global economic trends

It is important not to have a too technical perspective when research of this kind is conducted. Air and HSR are certainly technical systems, but the field involves a great number of social issues, including politics. A broad perspective appears crucial.

On the one hand it is obvious that the potential development of the systems in question are very much dependent on the development in the world around. Research in the field has to involve considerations of the evolution in corresponding sectors. A number of factors has influenced and will influence the future progress. It includes areas like economic growth, the increasingly internationalised trade and business, new information technology applications, traffic as well as environmental policy, public administration, etc.

On the other hand the technical systems in question also have impact on the world around. Does the development have potential positive side effects that the society can take advantage of? Are there any detrimental side effects for the society to handle?

Historically we have seen a co-variation between ***economic growth*** and transport volumes. Transport volumes have tended to grow faster than GNP. For international journeys this relationship has been particularly pronounced. There is a common believe that western (and other) economies in general will continue to grow. If so, will the economic growth coincide with increasing travel volumes also in the future? Are there reasons to believe that this development will continue along the traditional path or can we expect new trends?

The households private travel is closely linked to growth in disposable income and to the over all economic development. Humans in general tend to have a basic desire for certain journeys. Leisure travel is highly appreciated. The lust for new experiences

10 Important regional airlines are: Crossair, DLT (now Lufthansa City-Line), Air Inter, TAT, Business Air, regional APT is also operating to be found with leading European airlines, aircraft until 100 seats.

11 This increasing attractivity resulted in the permanent down-fall of the classical railways which, by us means, were able to match the APT advantages. Only as the high-speed rail was introduced at the beginning of the 80s, change started.

and change are fundamental. "Variety is the spice of life." Consequently it is natural

to expect that certain kinds of travelling will be given priority and increase when household economies grow. Tourism is a growing sector. On the other hand, there are trips people do not want to carry through. To the extent that circumstances admits people will strive to substitute such journeys. The over all development in the field tend to be a decrease in trips that people find undesirable, but an increase in desirable trips. An expected growth in the economy combined with decreased travel costs point towards increased over all private travel.

Internationalisation of the trade and business sectors has been a basic trend during the last decades. Large companies have bought domestic and foreign competitors, while others have merged. New production patterns have been seen. Such patterns often include global specialisation. A single article can be produced at a certain location for a large region like Europe or even for the whole global market. Economies of scale outweigh increased transport costs. A geographically spread business demands co-ordination. Despite the development and implementation of information technology, face-to-face contacts still are, and perhaps always will be, irreplaceable.

At the political arena increased, competitive international ***trade*** are seen as ***a catalyst for economic growth. Internationalisation*** has ***also*** been made a national and international ***policy***. The free mobility of goods, services, humans and capital are cornerstones in EU policy. Therefore transport policy has been an important focus for the union. Nationally developed transport systems, with national priorities and solutions has proved to involve some obstacles for transportation. Consequently it has been a priority for the union to attempt to eliminate inadequate connections between national networks including incompatible technical specifications, to build missing links and to remove bottlenecks within the transport system. Similar to the development in the private sector internationalisation of politics and administration contributes to growing demand on international travel.

Contemporary trends are shifts in the ***work force structure***. The number of contact and travel intensive employees are increasing, while travel extensive employees, including blue collar workers decrease considerably. A part of this development is the expansion of IT-related businesses. A sector characterised by high contact intensity. These changes in work force structure tend to contribute to increasing demand for business travel.

During the 1970th there were quite a widespread apprehension that modern forms of ***information technologies (IT)*** would have considerable effects in terms of travel substitution. According to this vision video-conferencing, telecommuting, tele-shopping, etc. would decrease the need for travel. At an individual level travel substitution has been recorded. The development has proven that IT also have counteracting effects. Trips are also generated. For instance, IT contributes to widen peoples contact nets, which in turn leads to additional travelling. IT results in time savings, setting time free for activities like travelling. So far we have seen a simultaneous growth of IT-communication and travelling. Physical movements and IT communication are complementary. The generating effects of IT tend to outweigh the substitutional effects at an aggregated level.

During the years, alterations toward decreased travel now and then has been foreseen or advocated. In the current debate arguments are raised for constraining travel due to ***environmental concerns***. Up to now environmental problems basically have been met by technical measures. Cleaner fuels and emission control equipment has lead to considerable reduction of emissions of air pollution. Noise barriers along roads and railways have limited noise disturbance. Purification plants have been built at airports to overcome problems with water pollution. Until now direct and indirect measures to influence transport patterns have rarely been implemented, but such instruments have been discussed. Such measures also bear on the fast growing congestion problems, especially in road traffic, but more and more even in air traffic. Problems that up to now, to a very limited degree has been fought by other measures than building additional infrastructure. A change of focus has occurred. ***Financial constrains*** also has contributed to this development.

Further interventions, due to environmental impacts are to come. The environmental problems are most distinct in cities. Thus, it is likely that measures will be aimed at such areas. Many European airports are located close to city centres. At a number of airports noise problems are severe, and acceptable technical solutions to the problems in question does not exist. At some airports traffic volumes therefore has been restricted. Still, air and long distance railway traffic are probably not market segments that primarily will be targeted by future policies. There are so far no evidence that environmental concerns will influence the travel volumes to any more extensive degree.

To summarise, there are a number of trends in the world around air and rail traffic that indicate increasing demand for transportation. It is particularly true for long distance travel. Most forecasts points in the same direction. In turn such a development threatens to increase ***congestion*** problems. Since years, congestion problems have been marked in many densely populated areas in Europe. Road congestion has drawn most attention, but also air traffic has met pronounced problems. Many European airports face problems with insufficient capacity. Often there are physical and environmental constrains for traffic increases. However, there seems to be considerable possibilities for capacity increases through technical development and organisational changes. A potential for capacity increasing road and air traffic have been pin-pointed as the main areas for future concern. It has been seen as a major political task to handle those issues. They are no longer seen as pure local or national questions, but also as regional problems to be included in the European policy. The European Commissions Green Book on fair and efficient pricing in transport points out such a strategy [3]. It describes policy options for internalising the external costs of transports.

One part of the strategy to handle the situation is to take advantage of excess capacity, where it may exist. The railway and inland waterways has been pointed out as under-utilised transport modes where excess capacity could be brought into service. A second part of a strategy is to increase the possibilities to combine and co-ordinate different modes to perform a certain transport.

The union's transport policy has come to focus on so called ***Trans-European Networks***. Networks aimed to guarantee smooth transportation not only within the EU but also to third nation. In the beginning of the 1990th a Trans-European high-speed rail network was presented. The use of common European funds, to overcome national financial constrains and influence national priorities, has been the major measure to promote such a development.

There seems to be good reasons to analyse future air and rail traffic in the context of an over all increasing market for long distance travel.

1.3.2 Tendencies in Air and Rail Traffic

Historically, the characteristics of air and rail traffic have been very different. Throughout the western countries state owned national railway companies are dominating. During the early development of airline systems most nations felt a need for national air companies. Ownership or partnership was a way to control and guarantee "satisfactory" supply of traffic. In parallel to those airlines, charter companies have developed. They have typically been ran as pure private companies. Railway companies have come to be ran as public administrations, but airline companies rather as businesses. International competition has demanded businesslike management.

During the last decades certain forms of deregulation or liberalisation has been seen in a number of European countries. The ambition is to increase traffic systems efficiency and service through increased competition. This development has been most marked for air traffic and to some extent for long distance bus traffic. In the railway sector however, the development has just started. There has also been a ***trend towards privatisation*** and an endeavour to run both the air and rail traffic in question in a businesslike fashion. A development of public-private partnerships has been a part of the evolution. The changes has probably been most marked for some state railway companies. However, the transformation has also been obvious for a number of airlines. Large scale co-operation is a current trend in aviation. The present view seems to be that global competition demands more or less global collaboration.

High-speed rail technology shrinks ***travel times*** considerably, at the same time as airlines have problems to cut travel times. Figure 3 use the Stockholm - Gothenburg relation to exemplify the development. The railway distance in the relation is 460 km. The figure shows travel times from city centre to city centre with different mode. For aviation ground connections also are included. What we can see is, that travel time with air still is at the 1968-year level. Travel time improvements due to the introduction of jet planes was counteracted by a relocation of the Gothenburg airport to a peripheral location. A rail link between Stockholm city and the Stockholm airport Arlanda (located 43 km from the city centre), however, will cut future travel times. In the end of the 1980s the Swedish State Railways introduced "City-express" in the relation Stockholm - Gothenburg. It was a classical direct train, that was given priority in the rail system. As indicated by the figure, the travel time was cut considerably for those departures. Still, travel times remained constant for most traffic. The introduction of the high-speed rail concept X 2000 cut railway travel times by about an hour compared to regular trains. The graph illustrates a future potential to cut travel times by the introduction of an improved HSR-concept.

According to such a scenario HSR travel times can come to be shorter than city to city air travel times.

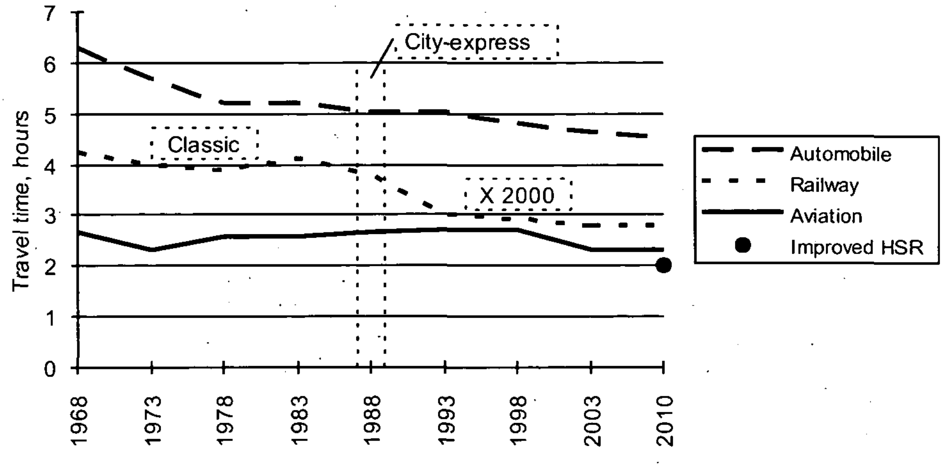

Figure 3: Total travel times between the city centres of Stockholm and Gothenburg with different modes. Actual development and forecast

Environmental concerns such as noise and air pollution, lack of land (for further expansion) are moderating factors for further expansion of many airports. In a similar way construction of new high-speed tracks are, besides economic restrictions also, constrained by land-use and nature conservation considerations. But still, environmental sustainability is a major argument for investments in railways. Noise considerations arise question of relocating centrally sited airports in favour of more peripheral locations.

The modern management of air and rail traffic reduce historical differences in management culture. Technical development, combined with airport capacity problems, has a similar influence on travel times. In some modern high-speed trains also service concepts are more airline-like. Altogether medium distance ***air and HSR traffic tend to converge.***

One can question the rationale for rail companies to implement (improved) "air-service-concepts" (X 2000, AVE). In a historical perspective those modern concepts not necessarily come out as exceptional or outstanding. When you compare them to the "Orient express" for instance, they may rather appear mediocre.

Current development has strengthened the elements of competition as means to achieve efficient transport systems. At the same time it is obvious that complementarity also has a potential to improve over all efficiency. This potential may appear most apparent when air and rail traffic are seen from travellers perspective. For instance, combined tickets allow them to choose one mode in one direction and the other in the other, if that is their desire. It could also make long and medium distance rail transport to an airport more affordable. From the society's view complementarity could be a way to use scare resources in a better way. To have both air and rail services at lines with limited travel demand is not necessarily the best solution. From perspective of the traffic companies co-operation provide better prerequisites for competing with road traffic.

1.4 The Idea of High-Speed Rail in Europe

Initially, HSR has mainly been seen as a new technology, evaluated according to the technical performance it was able to reach, especially in terms of maximum speed. It is to this respect quite significant that when the idea of a new link between Paris and Lyon first arose, because of the rail traffic congestion on this corridor, the hypothesis of a high-speed rail line has been considered just at the same level as other ones related to major advanced technology projects, such as the aérotrain (train with magnetic sustentation) and the ADAC/ADAV (planes with short or vertical take-off).

It is only thanks to the commercial success of the first experience of it between Paris and Lyon that the interest turned to the economic performance of high-speed rail, beyond the contribution to the energy independence that influenced the decision taken in the context of the first oil crisis. On the one hand, this new mode was demonstrating its ability to divert a significant share of APT market on the basis of door-to-door travelling time, and to generate a much higher increase of total traffic than expected from the forecasting models. On the other hand, it was possible to expand its efficiency far beyond the cities served by the new line, because of its compatibility with conventional tracks.

In the context of the crisis of rail facing the competition of road transport, both on the passenger and freight sides, and the commercial dynamism of domestic APT, at least in France, this appeared as an exceptional opportunity to give to rail transport some kind of new start. It consequently came to the building up of two new HSR lines in France concerning the Atlantic and North corridors, and to the launching of HSR projects in a number of European countries, including the adoption of long term national schemes for HSR infrastructure such as in France.

The development of such projects, some of them allowing for an interconnection (the best example probably being the Paris by-pass connecting the three French HSR new lines), led to the idea that HSR could do more than serving important corridors and constitute a network of its own. From that moment, it was becoming possible to think of it in global terms at the scale of the European territory.

Up to what extent can HSR act as a global network has obviously still to be cleared. It could well be that the market potential for very long-distance links served by night HSR remains rather limited considering the economic background of competition with air. It could also well be that extensions of HSR services on the conventional network be more important than connections between HSR new lines.

But even if restricted to middle-range distances (300-800 km) including part of the service at conventional speed conditions, HSR introduces an alternative significant enough to allow for such questions as :

- Is HSR able to keep environmental negative impact of long-distance system of transport within acceptable limits? Both for noise and air pollutants?
- Can HSR release the air congestion enough to prevent from restrictions of capacity to APT or from environmental-unfriendly airport investments?
- What could be the consequences of a growing complementarity between air and HSR networks?
- What could be the effects of HSR development on energy dependency?
- What will be in the long run the impact of HSR development on the profitability of conventional rail services? Can conventional rail tracks be to high-speed rail lines what national roads are to motorways?
- To which modifications of the land distribution of activities is leading the development of HSR network? Could it avoid to increase the polarisation on major economic areas?

Most of these questions are addressed thereafter in this report, in so far as, beyond the dimension of the evolution of the market shares among competing modes, interactions between air and rail may mean as well new ways to complement each other, new impacts on environment and so on. You will find in particular references to the complementarity challenge in chapter 2.4 and to the external effects in chapter 3.4.

1.5 Perspectives for an Analysis

The discussion on complementarity identify a generic question: For whom shall transport systems be designed. Shall they first and foremost be built for travellers, for businesses, for making business or for something else? The goal of national transport policy usually has multipurpose and aim at citizens' as well as at businesses' needs.

A comprehensive analysis of travel markets, as well as studies of conditions for competition and complementarity benefit from adoption of different perspectives - a perspective analysis is required[12]. An appropriate application of a the method calls for a treatment of travellers', the society as well as the traffic companies views.

12 Rationales and principles for a perspective analysis are developed in Engström et al 1997

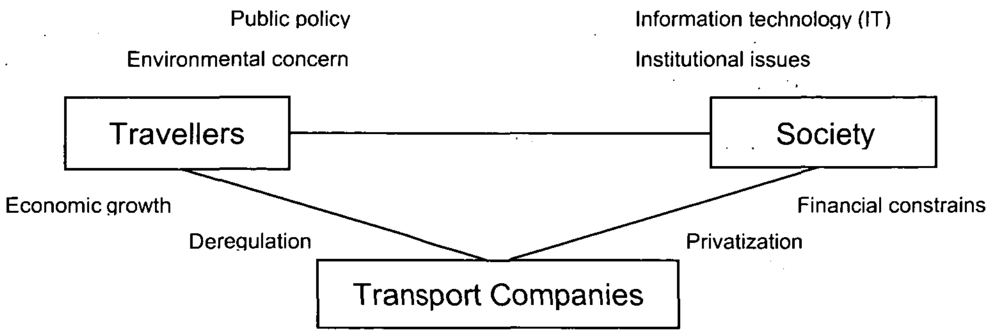

Figure 4 Perspective analysis. Central perspectives of an issue are analysed in respect to the development in relevant factors in the world around.

- In principle a journey has no intrinsic value. It's merit is the good it does for **the traveller**. Thus, when we analyse transport systems from travellers perspectives we start from a basic condition that offers possibilities to understand the over all benefits of a transport system. Individual travellers desire a supply that is as "good" as possible. Travel costs experienced as reasonable is an element of that desire. Basically, travellers want a smooth, comfortable and effective transport between two locations.

- **Transport companies** (and airport administrations, etc.) strive to supply services that attract sufficient travellers to gain profitability. The perspective also include the views of travel agencies, travel organisers, etc. Transport and travel enterprises are key actors in the transport market and have a decisive impact on system design. Thus, an understanding of their working conditions provides insights in system development. Insights in their business can also help identify unnecessary or outdated laws and regulations and to develop functional and fair rules. An analysis according to traffic companies perspectives can also pinpoint needs for additional infrastructure investments.

- **The general public** has a wider view on transport systems. Of course, travellers perspective has to be a major concern for the society but it also has to make other considerations. The transport system shall provide transport services sufficient to facilitate people and business transport needs.. Transports shall not cause unacceptable or undesirable external effects in other sectors. Issues concerning accessibility for minorities (disabled, countryside residents, etc.) is an other important field. In accordance with this description Swedish transport policy for instance points out five areas for special concern: efficiency, accessibility, environmental impacts, safety and promotion of a regionally balanced development.

Of course, there are considerable interrelations between the different perspectives. Thus, conclusions of a perspective analysis call for a global approach, where the important findings from all the perspectives are taken into account.

1.6 Air Transport as a Forerunner and a Model for High-Speed Rail

1.6.1 European Transport System

The European passenger transport system consists mainly of the three modes road, air and rail. These modes should yield connections to the main cities with reasonable travel times, not only on the national level but also on the European level. Distances and topology can support or hinder the different systems in fulfilling their transport task.

Illustration on Annex 3 shows the distribution of the big centres and main transport routes. We can distinguish very clearly the big agglomerations Paris, the Rhine-Ruhr region, and also London, Berlin, Hamburg, Madrid, Lyon, Milan and Rome, which seem to be suitable to be connected by HSR transport because of their distance to each other and their concentration of population since HSR can only be realised if there is a high demand, on routes with travel times up to 3 to 4 hours. Most of the 500 million European inhabitants live in about 300 cities with more than 200.000 citizens. Furthermore there are several less populated regions which, however, retain important urban areas. M. Walrave [4], the former secretary general of the UIC, named three remarkable zones on east-west axes. First, one corridor runs from the UK via continental Europe to Warsaw, where more than 140 million people live. Second, there is a central corridor between Paris, South-Germany and Budapest with about 80 million inhabitants and finally a southern corridor from Barcelona via Southern-France, Northern-Italy to Belgrade with 60 million inhabitants.

Figure 5 shows, that there is intensive air traffic between many of these centres, with at least 10 or 20, partly more daily frequencies, for example the connections London - Paris, Paris - Amsterdam or Paris - Frankfurt.

If we look to Germany we can recognise the expanded network of the air traffic (Fig. Annex 4). Presenting all destinations which can be reached in scheduled traffic from German airports we can see that the air traffic is able to offer services to numerous destinations directly, also in those cases, where the demand is not very high.

Rail is a competitor to air in some connections, especially HSR, which we can see in the illustration Figure 6. The already existent lines in France, Spain, Italy and Germany are strongly underlined. These single lines shall be completed by many new and upgraded lines till the year 2015. The future HSR network [4] will consist as well of a central part that corresponds to the part of Europe with the highest density of population and that connects the most important urban areas in those areas and with eight gateways to peripheral areas.

The gateways are:

1) London for Great Britain
2) Hamburg for Scandinavia
3) Warsaw for the Baltic states and Russia
4) Budapest for Moldavia and Russia
5) Belgrade for Balkans
6) Milan (Bologna) for Italy
7) Paris for Spain and Portugal
8) Barcelona for Spain and Portugal

The network should contain a good developed central part with a fast access from the border areas.

The third big traffic system serving long distance travel is the highway network. The illustration on Annex 5 shows the European highway and motorway system. Here we can see a strong concentration especially in the Central Europe (Germany, Netherlands and Belgium). However, the highway network alone does not offer a complete picture of the growing overloading on many parts of the network. In Europe 70% of the necessary roads already exists, but 15.000 km of motorways or high quality roads are to be built up to 2005, 40% of them in member states of the periphery of the European Union [5].

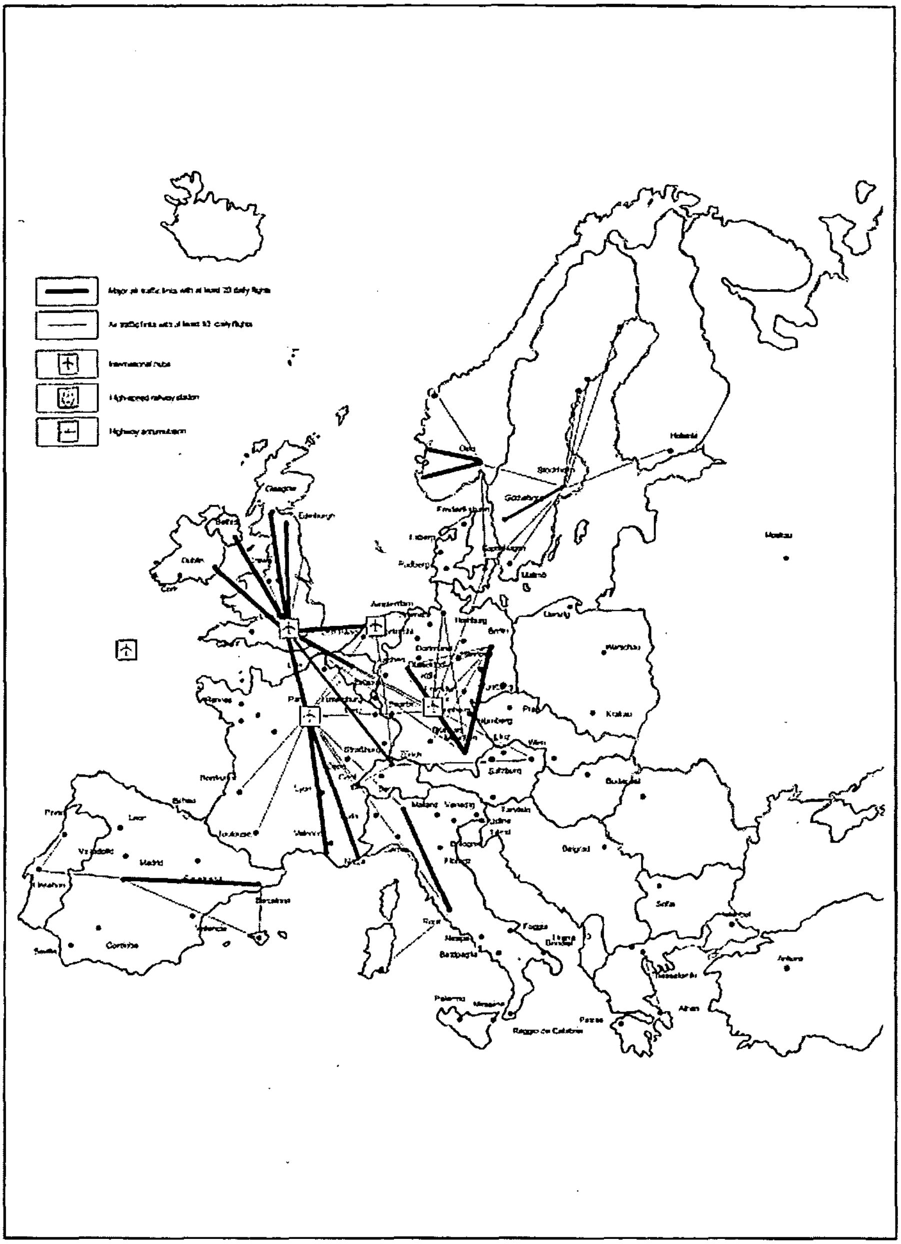

Figure 5: European Air Traffic Network 1995

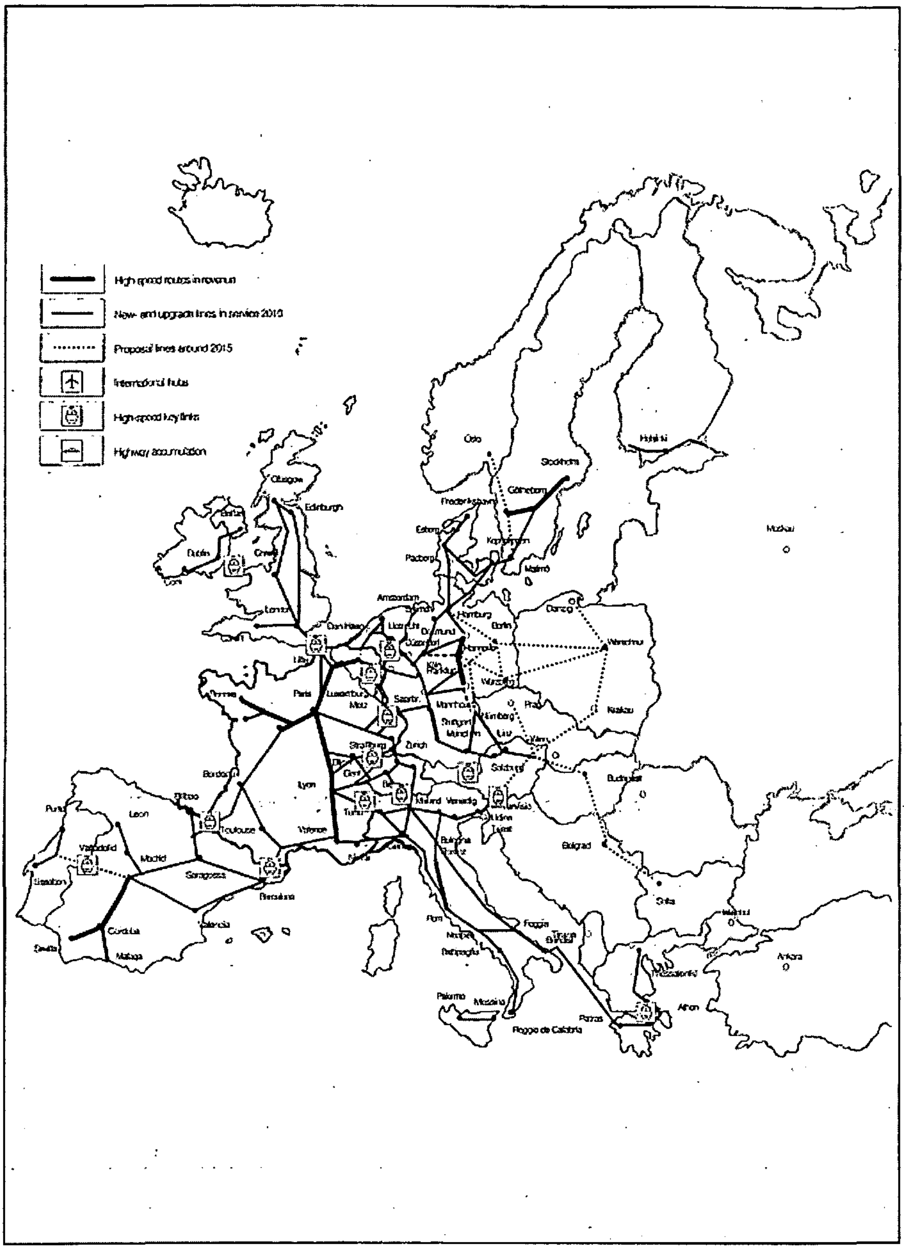

Figure 6: European High-Speed Rail System 2010

1.6.2 European High-Speed Rail Transport

Development of the high-speed transport

High-speed rail remarks an actual theme in the transport political discussion. The offer has been expanded considerably with many new lines, which established the European high-speed network with travel time speeds of over 200 km/h. While Japan has had early experience with the "Shinkansen", which connects Tokyo - Osaka since 1964, Europe did not think over a new railway system before the years between 1960 and 1970. This began with the fact, that extension of the Paris - Lyon and Florence - Rome link were necessary. Since the opening of the first line in 1981 the European high-speed traffic has strongly expanded and reached nearly 12% of the West European passenger railway traffic in 1994 [6]. At the beginning of the eighties, high-speed traffic has especially gained by the extension of the French lines [7]. Milestones were the completion of the ETR on the relation Florence - Rome, of the ICE on the city pairs Hanover - Würzburg and Mannheim - Stuttgart since 1991 and of the AVE on the route Madrid-Seville since 1992. In 1994 the TGV represented over 65% of the performance of the European high-speed traffic with 21,9 billion pkm, being followed by the ICE with 25% (8,2 billion pkm) and the AVE which already showed 0,9 billion pkm (3%) in the starting year. This means for France that the TGV reached more than 50% of the complete French railway traffic (Tab. 1-3). In comparison with the European high-speed traffic Japan reached more than twice as many passenger-kilometres with HSR traffic than Europe, although Europe has three times more inhabitants than Japan [8].

Administration	New lines >250km/h	Upgrade lines	Total (km)
SNCF	1232	4268	5500
DB	427	1755	2182
RENFE	471	0	471
FS	262	1682	1944
SJ		1089	1089
BR		777	777
SBB		249	249
Channel		50	50
Total	**2392**	**9871**	**12262**

Table 1: Length of the European high-speed rail 1994 [12]

Administration	Train	Commercial Vmax(km/h)[9]	Number	Seats/Train	Remarks
SNCF	TGV-PSE	270	108	368	
SNCF	TGV-A	300	105	485	
SNCF	TGV-Net	300	50	375	
BR	IC 225	225	31	550	
SNCF,SNCB,BR,	Eurostar	300	38	794	opening
DB	ICE	280	60	615	
RENFE	AVE	300	16	329	
FS	ETR 450	250	15	396	
	Pendolino				
FS	ETR 500	300	2	590	pre-series
SJ	X 2000	200	20	198	
Total			**443**		

Source: Jänsch,E.: Hochgeschwindigkeitsverkehr in Europa wächst zügig. in: ETR 5/94

Table 2: Survey of the high-speed trains in Europe

Administration	Billion km	Billion km/seat	Mio. km/train	average number of persons/train	average performance/train (km/year)
SNCF (TGV)	20,3	31,2	47,6	426 = 65%	375000
DB (ICE)	7,5	14,7	23,7	317 = 51%	465000
RENFE (AVE)	0,89	1,35	4,1	215 = 66%	260000
FS (Pendolino)	0,53	1,20	3,1	170 = 44%	210000
SJ (X 2000)	0,27	0,58	2,9	93 = 47%	170000

Source: Jänsch,E.: Hochgeschwindigkeitverkehr in Europa wächst zügig. in: ETR 5/94

Table 3: Performance in the European high-speed rail 1993, SNCF 1993

Paris with a length of 301 km was opened. In 1983 the route - which is served by the
In 1981, the first HSR line in Europe (Fig. Annex 6), the Southern part of line Lyon - TGV-South-East - was extended by 116 km and the top speed was raised to 270 km/h. The bypass of Lyon with a length of 38 km was raised 1992. In 1989 to 1990, the traffic of the TGV-Atlantique was taken up on the line Paris-Nantes [10], which has a length of 282 km. Day by day, more than 55.000 persons used the TGV-South-East and 52.000 persons the TGV-Atlantique since 1992. By bypassing Paris higher speeds can be achieved on the links between the North and the South of France. The number of travellers, who used the TGV-South-East grew by more than 90% between 1982 and 1992 and stayed constant since then. A load factor of about 80% has been reached. At the same time, the road traffic between Paris and Lyon developed less

than normal (+ 50% instead of 100 to 130% on other relations [11]). The traffic on the TGV-Atlantique route has already increased by 35% in the first three years, the load factor was 70% in 1992. 1993 followed the taking-up of the TGV-Nord with a length of a 333 km high-speed line from Paris over Lille to the Channel Tunnel. The connection London - Paris is reached with the Eurostar within three hours. The line from Lille to Brussels is already operating with a length of 71 km. In 1994, a link with a length of 70 km was built connecting the TGV-North and TGV-South-East. In the same year, too, the TGV-South-East was extended to Valence. For the year 2000, a network extension is planned from Paris to Strasbourg. Later this line shall be connected with the German ICE network.

In Germany the time of the high-speed traffic started with a project entitled "High-speed Traffic of the ninety years" in the year 1984 and the opening of two new lines with a length of 427 km on 2. June 1991 (Fig. Annex 7), the lines Mannheim - Stuttgart (100 km) and Hanover-Würzburg (327 km). In the first year 12.700 ICE-trains used the line with an average of 338 travellers per train and a load factor of 51%. As the distances between different population and economic centres in Germany are much shorter than in France, the performance in inter city-travel, measured in Pkms, is smaller, too [12]. In 1992, 14,5 million persons used the ICE, which achieved some 4,6 billion Pkms in that year. Because of the ICE the total inter city traffic of the DB grew by over 5% [11] per year between 1992 and 1994. On the ICE-train lines we can observe a growth of about 25%, on high-speed parts up to 50% in single cases. Big time savings lead to an increase of the load factor to 50%. In Germany the next upgrade will be realised with the opening of the new line Hanover - Berlin in 1998; since no other new line is envisaged, there will be only a small extension of the network in the coming years.

In Italy, 1988 was the begin of high-speed services with 15 trains of the ETR 450 or 500 on the DIRETISSIMA, a new line between Rome and Florence with a length of 262 km. (Fig. Annex 8). The service started, thus, three years earlier than in Germany. While only 695.000 persons used the ETR in 1990, in 1992 more than 901.000 persons used it, the factor of occupancy approached 50%. Before the year 2002 the new lines Turin - Venice and Milan-Florence will be taken up.

For the World Exhibition in Seville 1992, a new HSR line between Madrid and Seville was opened with a length of 471 km. (Fig. Annex 9). The travel time could be reduced to 2h 30 on this line by increasing the speed of the AVE to 270 km/h. Already in the first year the occupancy level was as high as 79%. The AVE services doubled their frequency and increased the factor of occupancy on this line even more, because of the growth of the demand and low prices, so the AVE-part of the Madrid - Sevilla market raised from 20 to 44% [11]. One third of the demand came from the air and one fourth from the road. A further part was the traffic generated [11]. A remarkable punctuality of 99% [13] is one the reasons for the high acceptance of the AVE by the public. In future a new line is planned between Madrid and Barcelona with a connection to the French high-speed line.

The agreement of Maastricht, reached in November 1993, calls for a network of Trans-European lines, for a stronger connectivity within the EU [14]. A stronger connection of the high-speed lines should be reached through the extension of the different lines so that a real Trans-European network is achieved (Tab. 4). The travel times should be divided by two on important relations and - as a consequence - an increase of the demand between 50 to 100% should be reached (Paris - London, Paris - Brussels - Cologne - Amsterdam, Paris - East France - South Germany, Cologne - Frankfurt) [15]. Of great importance will be the realisation of the new line Brussels - Cologne and the extension of the TGV-South-East to the Spanish frontier for better connecting main domestic lines [16]. The planned crossing of the Alps between Lyon and Turin shall connect the French and the Italian line. The new line Strasbourg - Lyon is important for the connections of the axis Berlin - Frankfurt - Barcelona. South Germany shall be connected with France by the TGV-East. The connections with Scandinavia require important sea crossings. So the high-speed traffic needs a bridge between Copenhagen and Malmö to Stockholm and Oslo. A further requirement is a solid crossing of the Fehmarnsund.

Building up a European network

Interoperability

The description of the demand for HSR services is difficult, because national railway administrations do normally not give out data describing the origin-destination-demand. So the description will be restricted to qualitative statements for the most part, which were found in literature. Several aspects regarding the realisation of a European network are to be considered. First it is important, to reach a standardisation of the different parts. There are national differences in the gauge, in engineering, in the signalling and energy system. While nearly all European states have a standard gauge (1435 mm), there are differences in the USSR, Spain and Portugal. The first Spanish high-speed line AVE between Madrid and Seville, however, has already been built in the standard gauge of the European high-speed traffic. The former states of USSR have agreed to construct the lines to Moscow in standard gauge. There are also great differences in the electric power supply in Europe; since a standardisation is not yet agreed upon, some border crossing train equipment are constructed with different current systems. A common utilisation of several railway systems is possible on this way. Of course, the weight of these trains will increase through the additional equipment, leading to lower average and top speeds. The different signal and communication systems of the national systems are a further problem. However, for the time being, the only practical solution is to equip the trains with different systems.

EXISTING				
Year	**Land**	**Train**	**Destination**	**Length (km)**
1981	France	TGV-Sud-Est	Paris-Lyon	301
	Italy	ETR	Direttissima Florence-Rome	150
1983	France	TGV	Paris-Lyon	116
1984	Italy	ETR	Direttissima	74
1988	Germany	ICE	Würzburg-Hanover	90
1989	France	TGV-Atlantique		176
1990	France	TGV-Atlantique		106
1991	Germany	ICE	Würzburg-Hanover	237
	Germany	ICE	Mannheim-Stuttgart	100
1992	Spain	AVE	Madrid-Seville	471
	Italy	ETR	Direttissima	24
	France Sweden	TGV-Sud-Est X 2000	Bypassing Lyon Stockholm-Gothenburg	38 460
1993	France	TGV-Nord		333
1994	Great Britain/France	Eurostar	Channel Tunnel	50
	France	TGV-Sud-Est	lengthening to Valence	83
	France	TGV-Sud-Est TGV-Nord	Connection	70
1996	Belgium		Brussels-Lille	71
	France	TGV-Atlantique	Connection	32
Total				**2982**

Table 4: Development of the European high-speed network

Planned				
Year	**Land**	**Train**	**Destination**	**Lengths (km)**
1998	Germany	ICE	Wolfsburg-Berlin	158
	Germany	ICE	Wolfsburg-Braunschweig	12
	Germany	ICE	Uelzen-Stendal	15
	Belgium		Brussels-Aachen	84
	France	TGV-Sud-Est	lengthening to Marseilles	295
up to 2002	Germany	ICE	Cologne-Rhein/Main	186
	Germany	ICE	Leipzig Nuremberg	190
	Germany	ICE	Nuremberg-Munich	90
	Germany	ICE	Karlsruhe-Offenburg	70
	Austria		Vienna-Bruck an der Mur	35
	Great Britain		London-Channel	110
	Spain	AVE	Madrid-Barcelona	606
	Italy	ETR500	Torino-Venice	414
	Italy	ETR500	Milan-Firence	264
	France	TGV-Est	Paris-Strasbourg	303
	France		Mulhouse-Bourgogne	190
	France		Lyon-Montmelian	107
	France		Tours-Bordeaux	361
	France/Spain		Perpignan-Barcelona	174
	Belgium/Netherlands		Brussels-Amsterdam	186
	Denmark/Sweden		Copenhagen-Malmö	46
Total				**6878**

Source: M.Walrave : Le project de reseau european a grande vitesse. in Transports 2/93

Table 5: Development of the European high-speed network (continuation)

Network

Railway companies work hard along these lines, and a part of the border crossing connections has already been realised (for example from Paris to Brussels and to the Channel Tunnel). Services have been extended substantially through the taking-up of different new high-speed lines in the last 5 years. The existing lines have different functions, they support a better supply in the national part and relieve other network functions. Furthermore, the sections are important components of the European high-speed network, which are to be connected internationally. In this context, several connecting lines have already been realised nationally in France, around Paris, to connect the TGV-South-East, and -Atlantique and -North-lines. The new line between Paris - London - Brussels - Amsterdam - Cologne - Frankfurt (P/LBKA-line, Fig. Annex 10) is important, because it is a part of the planned East-West axis Paris - London -Brussels - Cologne - Berlin - Warsaw with an extension to Moscow - St.Petersburg and will be connected with the German high-speed lines.

Development of the network / link lines

The description of the national sections indicates that the key links are important for the European high-speed network because only the key links can create a continuous network, that makes possible to benefit from the attractive high-speed.

The region Southwest-England, the Benelux, the Rhine-Ruhr-area, North-France and the region of Paris have the highest density of population and the highest traffic volume. The EU has decided to build the first section of the network especially for connecting the UK to the European continent with the P/LBKA- line (key link), because there is a high demand for fast connections in these regions. The UK will be linked by a new line to London. London is already connected to the European HSR network by the channel. From London upgraded lines to Edinburgh and Glasgow will be built. By this time, a speed of 225 km/h is possible on the route to Cardiff. Another key link is the connection of Dublin to the high-speed network.

The HSR links within France offer a transit between Southern and Northern Europe, too. For this function the French leading idea provides for two North-South axes with the corresponding links to the adjacent networks. Beside the TGV-North there are additionally five key links in France. The TGV-Est and the TGV-Rhine-Rhone connect on the one side Germany and on the other side South-France and Spain with the central network. In future, an alpine traversing link will connect Lyon with Turin and Milan. Two further routes which follow the Mediterranean and Atlantic coasts form additional links to the Iberian peninsula. For connecting with these countries it is necessary to build axes of high productivity west and east of the Pyrenees (2 key links) which lead to Madrid and from there to Andalusia (1992) and Portugal (key link).

After the re-unification of Germany new high performance routes to the East will be needed. Just as in France mainly North-South routes had been built or have been completed up to now (Hanover - Würzburg, Mannheim - Stuttgart, Cologne - Frankfurt, Karlsruhe - Basle, Stuttgart - Munich and Nuremberg - Munich). Now the planning of East-West connections is intensified (Berlin/Ruhr-territory). Further links to Scandinavia, France, Switzerland, Austria and to the Benelux countries are projected.

In Switzerland new high-speed routes Basle - Bern - Lötschberg - Milan and Basle/Zurich - St.Gotthard - Milan are planned to provide for higher speeds. Other connections are projected to France and Italy via Lyon - Turin - Milan.

And to Austria new routes are provided between Germany and Italy (Munich - Innsbruck - Brenner - Verona as well as Vienna - Graz - Tarvisio - Venice).

After opening up the Italian high-speed network in 1998 there will be a West-East axis Turin - Milan - Verona - Venice and a North-South axis Milan - Bologna - Rome - Naples. It will be necessary to construct permanent crossings over the strait "Großer Belt-Öresund" (under construction) as well as over the Fehmarn Belt for linking up Scandinavia with the continent. Caused by the radical change of international politics in Central and East Europe the extension of the network to these countries is required.

The West-East axles Vienna - Warsaw and Berlin - Budapest as well as the linkage Kattovice - Vienna - Venice and Hamburg - Berlin - Prague - Budapest are regarded as important connections. An upgrade line between West and East Europe for 160 km/h is planned but a new line has to be built as fast as possible.

Finally, the connection of the Balkan states and Turkey makes possible to link Greece with the HSR-System in Central Europe. Long sighted the high-speed net will have a length of 29.000 km in the EU-countries and the alpine transit countries. 12.500 of them will be new lines. For total Europe (without USSR) the net will have a total length of 35.000 km with 20.000 km new lines.

1.6.3 Air Transport in Europe

Development of air transport

The history of APT has been described in chapter 1.2.2. By the time of 1925 a European wide air traffic network existed already (Fig. Annex 11). As we may consider the start of APT between both world wars[13], (classical) railways networks in Europe already existed. It was at this stage obvious that APT challenged railways, and this not only between main capitals separated by waters[14].

After breaking down caused by the World War II the APT received a fresh and enormous impetus, that lasts until now (Fig. Annex 12). In the 60s stronger international competition started between airlines which were protected by their national governments. The USA introduced the Deregulation Act in 1978 („overnight"), resulting finally in a throat-cutting competition between US airlines in the domestic market.

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13 Thus the real development of commercial APT in Europe began just after the end of World War II

14 In 1924, SABENA introduced an air route Rotterdam-Brussels-Strasbourg-Basle, aimed at challenging the railways. The flight between Brussels and Basle lasted about 4 hours.

In the European Community, liberalisation started in the middle of the 80s with a first package. The increasing competition led to further increasing air traffic rates, an improvement in supply of services, but also with the first limits of profitability in civil aviation. So, until the end of the 80s many airlines were in a financially bad shape and had to undertake rationalisation programmes reducing staff and supply, merges and cooperations of optimisation (code sharing), to cope with the price down-fall.

This process of liberalisation in aviation is still going on, the third and last package. Further, same European countries began with the privatisation of airports (e.g. British Airport Authority), but the consequences cannot be estimated for the time being.

The increase in air traffic volumes taking place results more and more in capacity-problems, especially with infrastructure facilities of airports which cannot be extended anymore because of the existing settlement density surrounding.

But some experts also are convinced that there is a possibility of further extensions at large airports. There are also possibilities for diversion of regional flights from the big airports to smaller, less congested airports. Other operations to gain capacities are: to shorten the aircraft separation in the sequencing process, new approach facilities (MLS), the extension of airspace routes (GNSS) and the reduction of military controlled zones. One alternative could be also the construction of new international airports out of the cities (like in Asia: Osaka, Hong Kong) in order to relieve large airports, but the ability to reserve land for this use is a sensitive task.

On the 274 member airports of the ACI, which present 90% of the European airports, in 1995 more than 730 million passengers and 14 million movements were handled. Furthermore 10 million tons of freight and 1,2 million tons of mail were carried. The major airports in Europe are nowadays London-Heathrow with 54 million passengers, Frankfurt (38 million) and Paris-CDG (28 million). The biggest European markets are the routes to and from Great Britain. A decrease in the number of passengers, however, can be recognised on links to London since the opening of the Channel Tunnel. The importance of the EU-market can be seen on the routes Brussels-Helsinki, -Stockholm and -Vienna where a growth of 28% between 1994 and 1995 can be regarded.

Development of air transport in Germany

After the World War II the extension of the German airport network started once more. During the blockade of Berlin in the year 1948 the great importance of the aviation was demonstrated. With the beginning of the blockade Frankfurt-Rhine-Main develop to the major airport of Germany. Already in 1946 the first civil APT connections between Hamburg and London, Amsterdam, Brussels and Copenhagen were opened. After adding again the airport of Munich to the APT network in 1948 as well as Stuttgart, the airline PAN AM started in this year a route, which connected Brussels via Stuttgart to Vienna.

While Cologne-Butzweilerhof was used by the Royal Air Force, a new runway was built under the British occupying power. The former airport Hanover-Vahrenwald did not exist anymore, so Hanover had no airport at this time. On the occasion of the Hanover-fair and with the support of the city master builder Hillebrecht in 1951 a development plan for the airport Hanover-Langenhagen with two runways was presented. Already in 1952 regular APT services were taken up. With the building of a runway of 1.200 m in the year 1950 by the cities of Nuremberg and Fürth and the region of North-Bavaria were connected with the APT network. Already in the year 1955 the provisional facility was improved to become the present airport of Nuremberg. After the Saarland was allocated the FRG in 1957, the airport Saarbrücken-Ensheim adapted to the modern APT standard and started scheduled air traffic in 1967. So the network of West-German airports had 11 airports.

In spite of the strong growth of flight movements until 1995 the growth rates are declining, which partly can be explained by the use of bigger aircraft. Concerning the number of passengers carried we can observe that the volume was already in 1950 more than 50% higher than before the war. During the time period from 1950 to 1995 the number of passengers increased from 654.000 to 110 million *(Tab. 6)*.

In 1950 only every fifth passenger of the 655.000 passengers started a journey to a foreign country. 12,5 passengers were carried on average per flight with small prop aircraft (e.g. DC3). Already in 1951 the number of passengers increased to 1 million. Due to the economic boom in the fifties the demand for air travel increased, so the number of passengers increased to more than 10 million. Caused by the conversion from prop aircraft to jet aircraft many more direct destinations could be reached. Caused by the higher efficiency of these aircraft travelling got less expensive and a charter APT started, which fostered the growth of demand for APT. With the start of operating high capacity aircraft in 1970 for long range traffic and in 1976 in short and medium range traffic, aircraft transportation became a mode of transport for a high number of passengers. Despite of the increase in the number of high capacity aircraft, the demand for smaller prop and jet aircraft grows since the mid of the eighties for completing the existing network and serving relations with a low volume. By that means the APT supply could expand in less populated regions and has been conducive to reduce the disadvantage of location and to improve the chance of competition in different regions.

Airport/Year	1950	1960	1970	1980	1985	1990	1995
Berlin	200493	1534624	5538399	4480242	4552994	6719684	11016467
Bremen	5305	56218	431250	663958	732311	1105022	1471533
Dusseldorf	55376	782296	3520424	7060841	7913532	11933591	15146500
Frankfurt	195330	1903932	8828926	16834426	19542520	29619332	38179543
Hamburg	110346	882660	2987616	4334087	4675338	6861255	8201463
Hanover	10552	532475	2363269	1952981	1947925	2814244	4270832
Cologne	-	208127	1276893	1919107	1960504	3086468	4740144
Munich	53004	688604	3361044	5730627	7653318	11423838	14867922
Nuremberg	6873	105442	510621	771194	893705	1472226	2250694
Saarbrücken	-	-	58345	161302	162094	256759	376461
Stuttgart	16793	248185	1551563	2620234	2947000	4423229	5158514
Total	**[654072]**	**[6943564]**	**30428350**	**46528999**	**52981241**	**79715648**	**105680073**
Münster						288909	939542
Dresden						-	1686583
Leipzig						-	2093522
Total						**[80004557]**	**110399720**

Source: Treibel, W.: a.a.O., ADV and ACI

Table 6: Development of passenger growth at German airports from 1950 – 1995

Airport/Year	1950	1960	1970	1980	1985	1990	1995
Berlin	9378	35282	77571	56253	55927	106068	220641
Bremen	1078	8833	18109	27192	28128	53021	50054
Dusseldorf	6162	45579	71550	87758	89829	155029	184125
Frankfurt	13126	81087	175788	211495	225431	324387	378388
Hamburg	11614	37742	64353	65870	73092	141042	149011
Hanover	928	27092	45175	48694	45580	95498	95413
Cologne/Bonn	-	15255	32732	52289	50393	118936	133399
Munich	5332	34104	72553	95205	114144	191856	213951
Nuremberg	1452	9199	11489	16752	24038	71740	79424
Saarbrücken	-	-	4793	14733	12660	26807	13320
Stuttgart	3220	25812	46636	57558	60628	124295	129589
Total	**[52290]**	**[319985]**	**620749**	**735799**	**779848**	**1408679**	**1647315**
Münster						56470	61087
Dresden						-	49581
Leipzig						-	53807
Total						**[1465149]**	**1811790**

Source: Treibel, W: a.a.O., ADV und ACI

Table 7: Development of frequencies on German airports from 1950 - 1995

With more than 38 million passengers (700.000 transit) in the year 1995 Frankfurt has strengthened its position as the biggest German airport, followed by Dusseldorf and Munich. The routes with the highest volume are connections between Frankfurt and Dusseldorf to Munich and Berlin.

In the following section, the focus will be on the development of 10 intra-German and 50 European destinations from Germany. 7 of 10 destinations with the highest passenger volume are German destinations, the other three are from Germany to London, Paris and Zurich (Fig. 7 and 8; Fig. Annex 13).

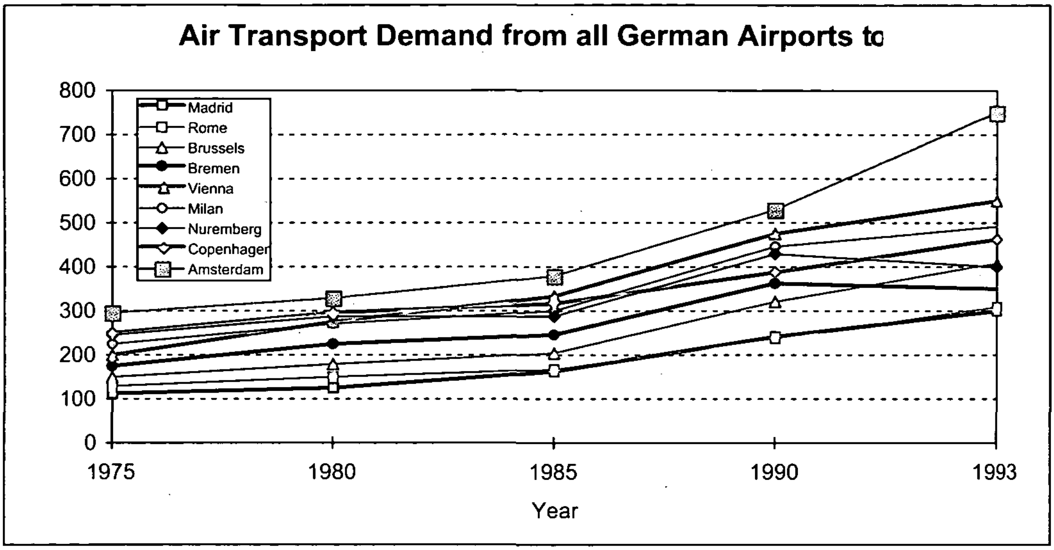

Figure 7: Development of Air Transport Demand on Different City Pairs (1.set)

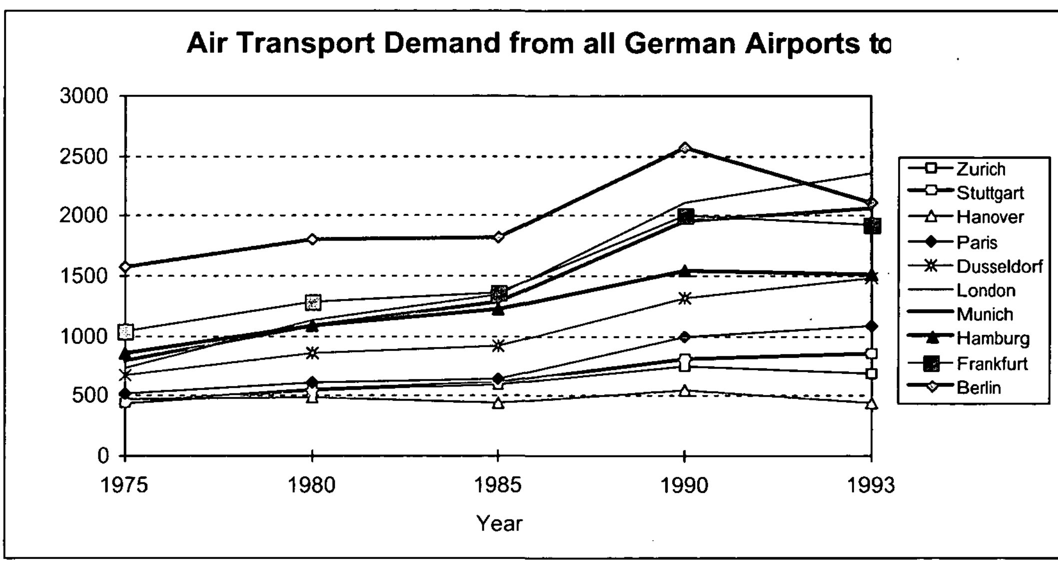

Figure 8: Development of Air Transport Demand on Different City Pairs (2.set)

1.6.4 Comparison of the Development of High-Speed Rail and Air Passenger Transport

Comparison of the development on several routes

Paris - Lyon

The TGV-Sud-Est on the route Paris-Lyon has been able to increase the number of rail passengers in the years 1981 to 1990 on this route by 90% (Fig. 9), although the number of train services has not been increased, proportionally in this time, because additional trains were not available. In the year 1990 the TGV-Sud-Est already carried 19,1 million passengers with 11 billion passenger kilometres, and had a share of 23% of the total long distance transport of the SNCF in this year.

APT declined strongly on the route Paris - Lyon (Fig. 10) in the time period 1981 to

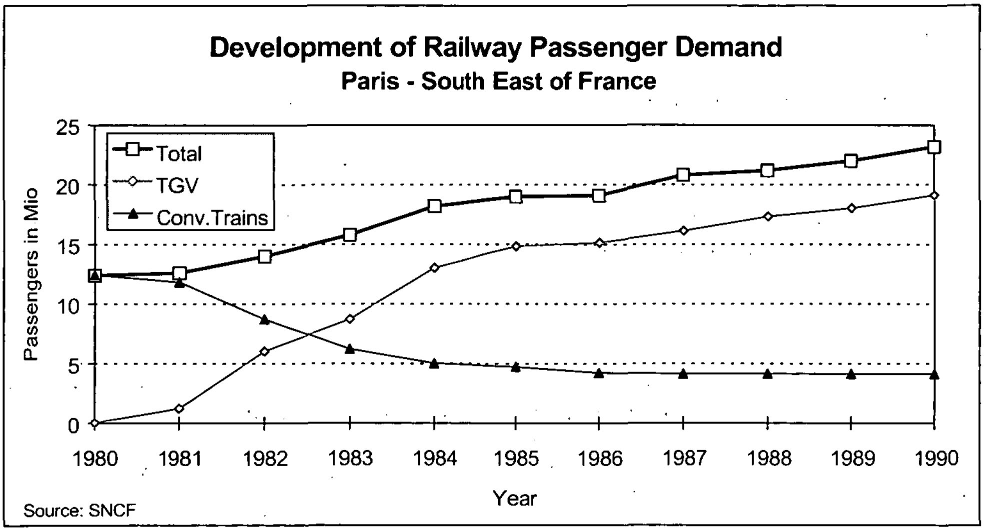

Figure 9: Development of Railway Passenger Demand

1990. There had been a strong fall of demand from 1980 to 1985, followed by a stagnation till 1990, and since then demand grew again. It can be seen that the modal split between air and HSR transport does not change anymore and that now both modes of transport will further develop side by side. Concerning the extension of the high-speed route to Marseilles, HSR transport with travel times of more than 4 hours does not offer a useful alternative [17] to most air travellers; the number of air passengers on that link has continuously grown since 1980.

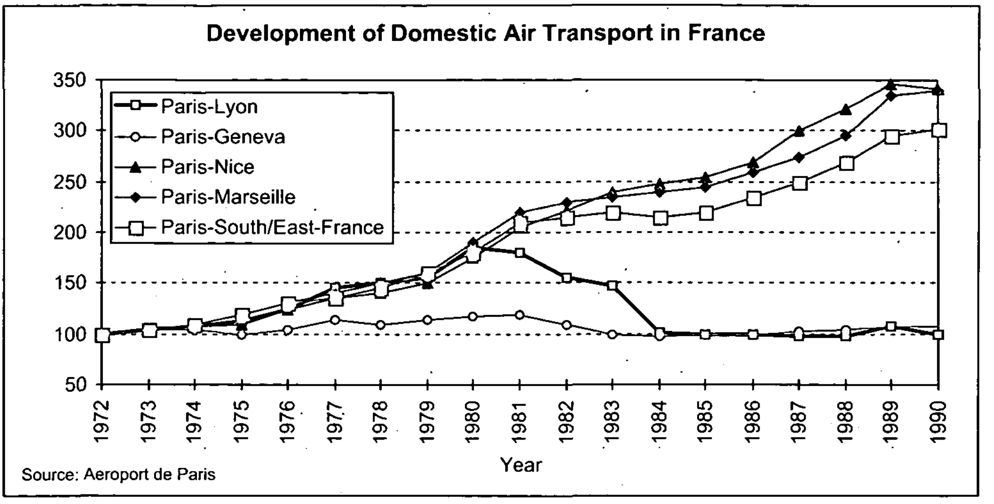

Figure 10: Development of Domestic Air Transport in France

The illustration in Figure 11 shows the development of air passenger demand from London abroad before and after the introduction of TGV

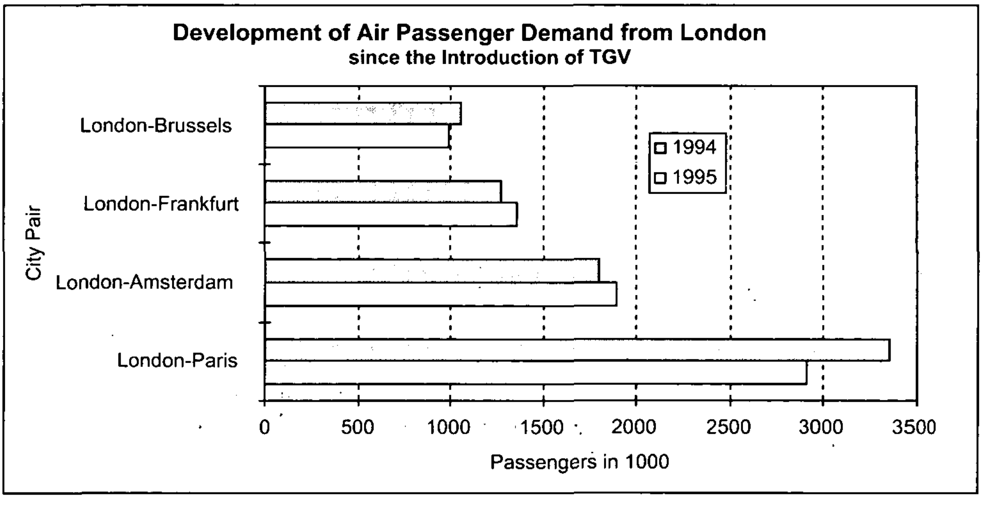

Figure 11: Development of Air Passenger Demand from London

Madrid - Seville

On the route Madrid - Seville the market share of air decreased from 14% in 1990 to 9% in 1994 with the opening up of the AVE. The car share has dropped on this route from 61% to 42% The share of rail has grown with the opening up of HSR transport from 13% to 41%. Most of the customers of the new AVE are either former air passengers (42%) [18], new customers (induced traffic 15%) or have changed from the car (20%) (Fig. 12 and 13).

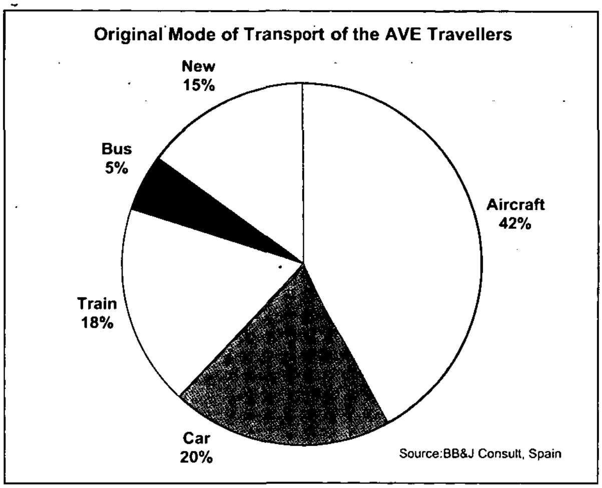

Figure 12: Original Mode of Transport

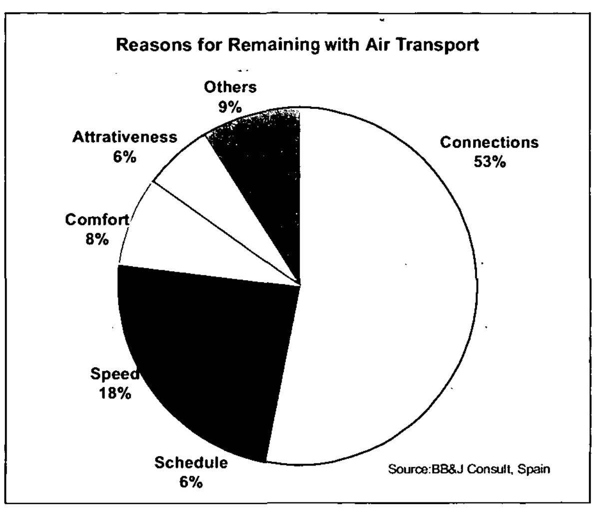

Figure 13: Reasons for Remaining with Air Transport

The Figures 14 and 15 show clearly, that there has been an increase of rail passengers and a decrease of air passengers in the first year of the AVE in 1993.

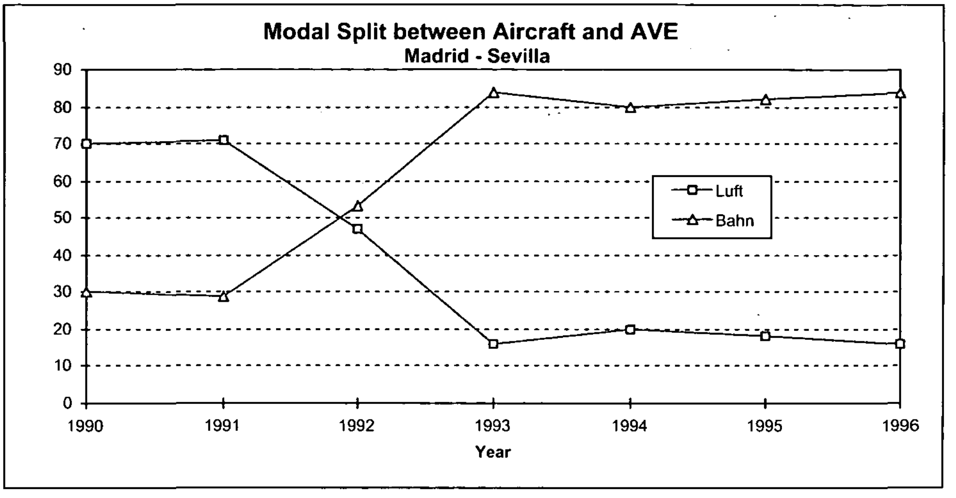

Figure 14: Modal Split Aircraft - AVE

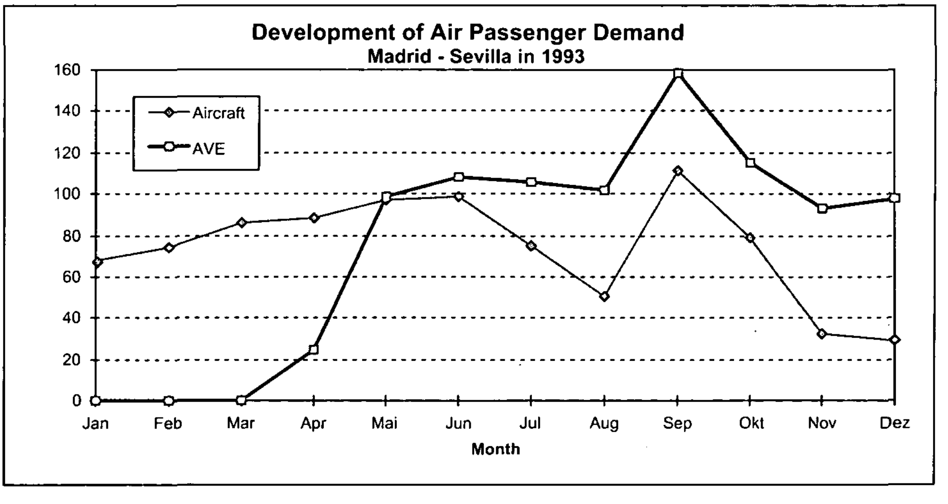

Figure 15: Air Passenger Demand 1993

Looking at the Figure 16 the decrease of air passengers continued until 1995. On the link between Madrid and Malaga a strong decrease of air passengers can be recognised in the year 1993 with the opening of the AVE. But it was followed by an increase again, so that in 1995 the passenger volume was higher than in 1992. The shortening of travel time of 7h20 before the opening of HSR transport to 4h50 with the AVE influenced the travellers to change the mode. In spite further shortenings of travel time to 4h10 many passengers choose again the APT mode. The comparison of travel behaviour on the link Madrid - Malaga and Madrid - Seville supports the hypothesis the HSR competes not successfully on links where the travel time is more than 4 hours.

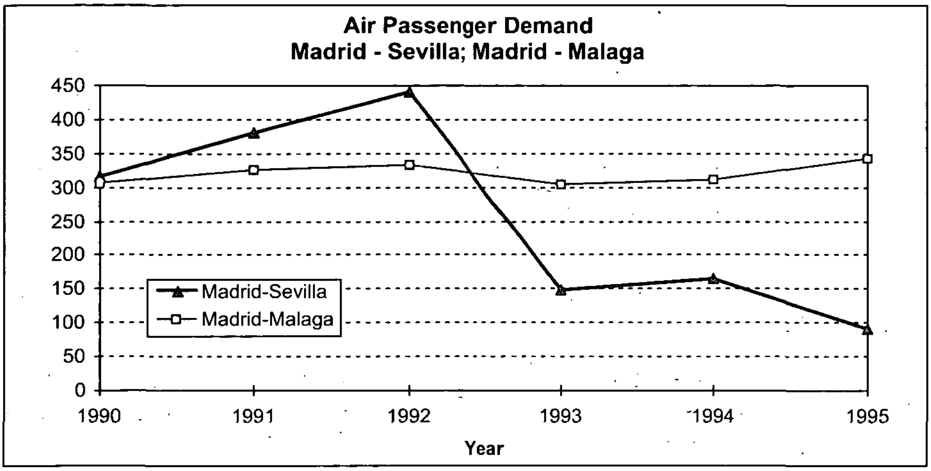

Figure 16: Air Passenger Demand on Rival Links with AVE

Hanover - Frankfurt

On the route Hanover - Frankfurt (Fig. 17) the passenger volume increased from 1991 to 1992 by 36% after opening up the ICE- transport. 25% of these passengers came from air and 11% from road. There was no induced traffic observed on this route in this year.

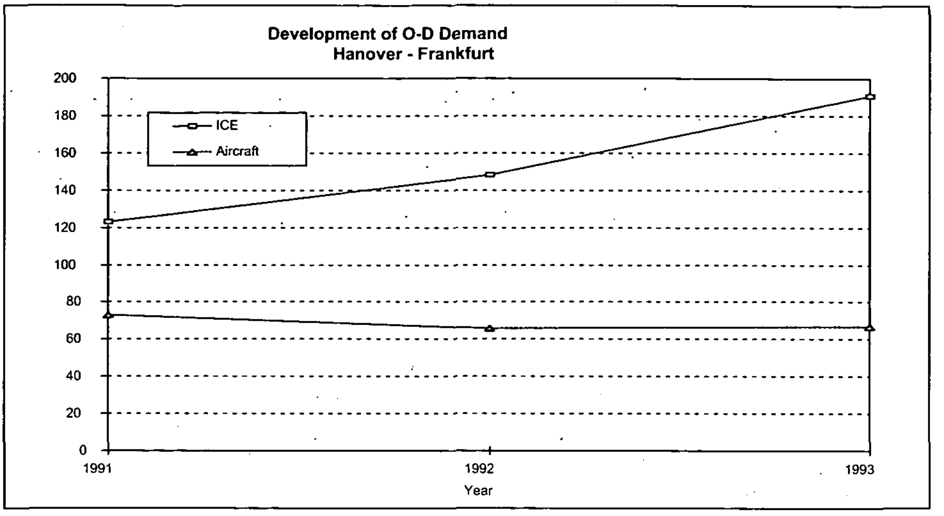

Figure 17: O-D Demand Hanover-Frankfurt

Frankfurt - Stuttgart

Frankfurt - Stuttgart (Fig. 18) had a passenger growth of 21% since the opening of the ICE in 1991 to 1992. 2% were induced traffic, 3,6% were former air passengers and 15,8% changed from the car.

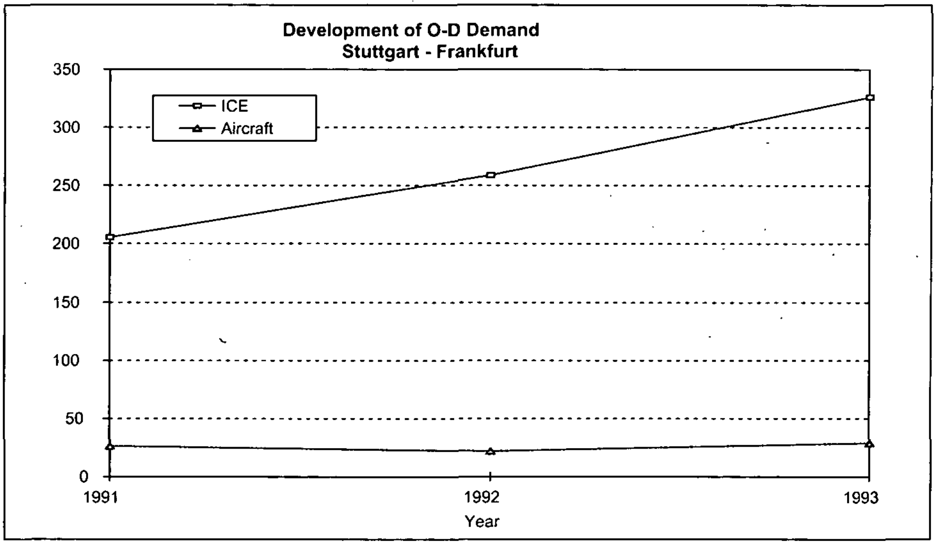

Figure 18: O-D Demand Stuttgart-Frankfurt

Frankfurt - Munich

Between Frankfurt and Munich (Fig. 19) the number of passengers grew by 23% from 1991 to 1992. The reason was, that many travellers (13%) changed from air to HSR. Less than 10% did not choose the car anymore but the train and about 1% was induced traffic.

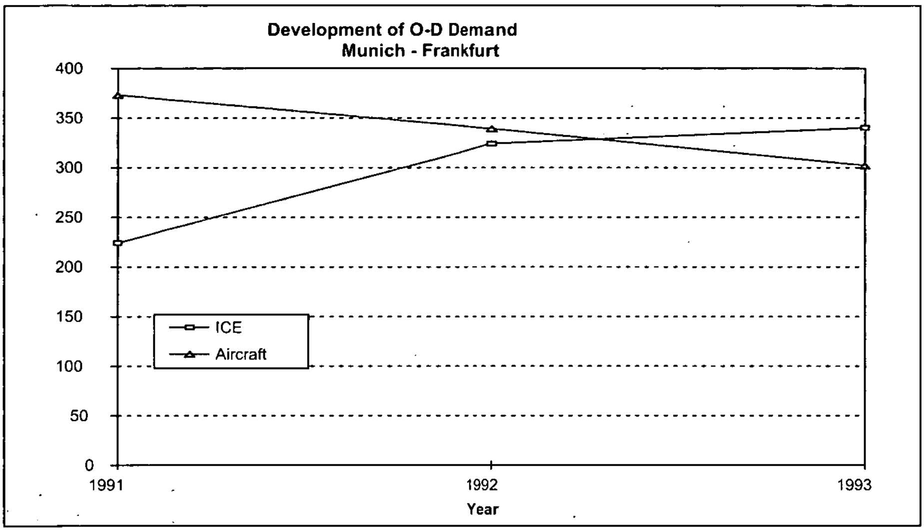

Figure 19: O-D Demand Munich-Frankfurt

Hamburg - Frankfurt

According to the information of the Deutschen Bundesbahn the passenger volume on the route Hamburg - Frankfurt (Fig. 20) increased by 40% between 1991 and 1992 as on the link Hanover - Frankfurt this generation effect was, caused by the opening of the ICE. Most of the passengers (25%) changed from APT, 13,4% were user of cars and 1% was induced traffic.

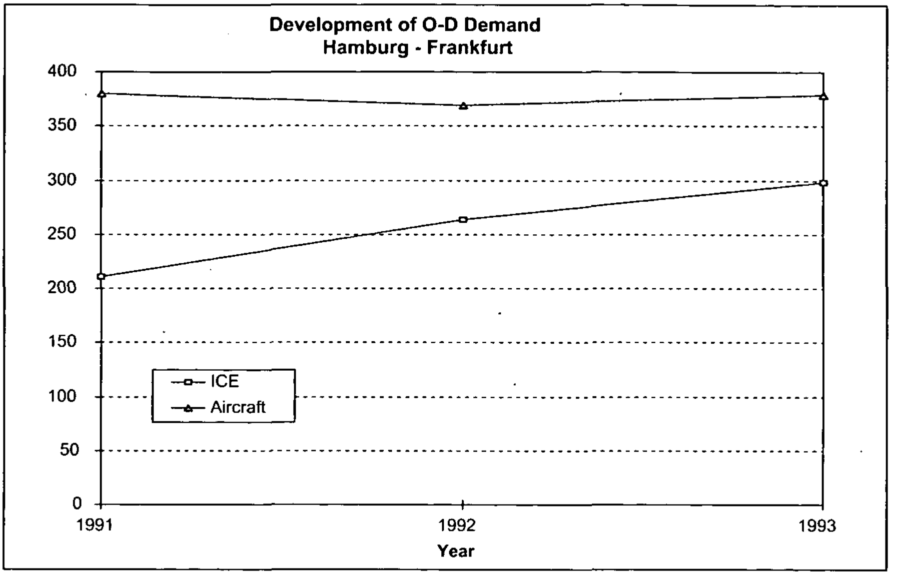

Figure 20: O-D Demand Hamburg-Frankfurt

The comparison of the origin destination (O-D) demand for HSR and APT on the four selected links Munich-Frankfurt, Hamburg-Frankfurt, Hanover-Frankfurt and Stuttgart-Frankfurt shows that the demand for rail grew on each route but that the demand for air decreased only on the relation Munich-Frankfurt. The small losses on the other routes between 1991 and 1992 were caused by other factors, among others the Gulf-war, the demand grew again between 1992/93 to the level before the war. A hypothesis could be that the expectations of the passengers changing from air to rail did not fulfil and that they then chose APT again. Another explanation could be the general increase of APT demand.

Looking in this context at the total air passenger volume (O-D demand and transfer passengers) on these routes there is a decrease too, on the short distance links Frankfurt-Stuttgart and Frankfurt-Munich. It can be shown, however, that long distance routes like Hanover-Munich or Hamburg-Munich, which have rail travel times of 4h10 respectively 5h08 are not well suited anymore for attracting passengers from air; these routes have a stable growth in APT. So there is a time limit, up to which the passenger accepts to change from air to HSR transport. The investigation of modal shifts on 25 city-pairs has shown that a change in modal choice took place where scheduled rail travel time is less than to 3 - 3,5 hours. On routes which have such travel times there has been a decrease of air passenger volumes between 10 - 70% after opening up the HSR transport with only two exceptions. On the other links with rail travel times above this time limit there has been a further growth of APT volume (Fig. 21).

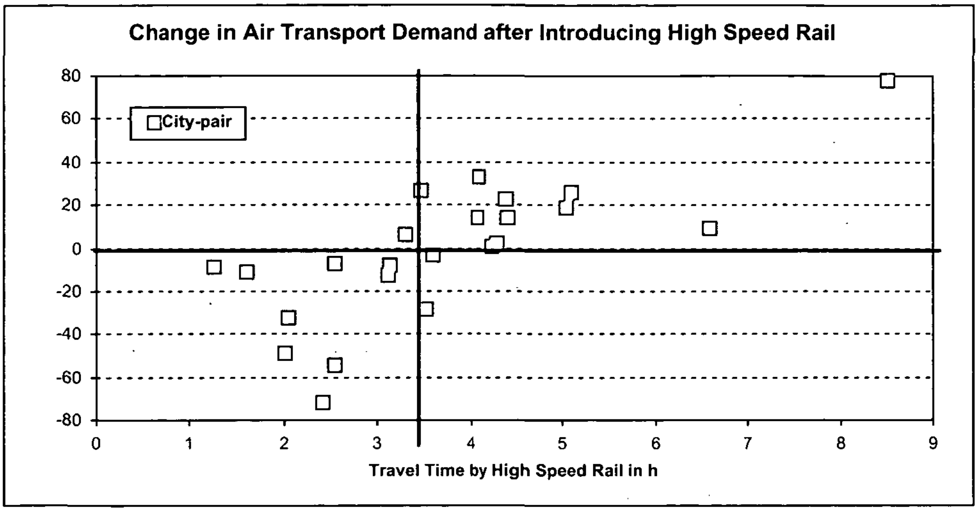

Figure 21: Change in Air Travel Demand

Stockholm - Gothenburg

On the route Stockholm - Gothenburg passenger volume in air and conventional rail transport decreased with the opening of the so called high-speed connection (200 km/h) in the year 1990 (Fig. 22 and 23). Already in the first year of the high-speed route 200.000 passengers were transported. In the second year the growth slowed down. At the same time the decrease in APT slowed down, too. Since 1992 there is a nearly parallel increase in APT as well as in HSR transport. A little stronger growth in HSR transport since 1993 is caused by the decrease in conventional rail transport. This example shows that passengers accept both the aircraft and the high-speed train and that both modes of transport have their clientele.

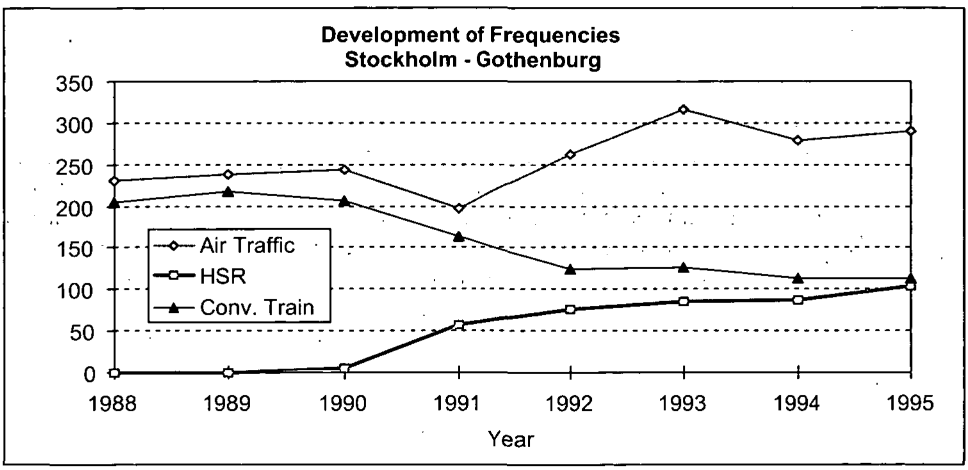

Figure 21: Frequencies Stockholm-Gothenburg

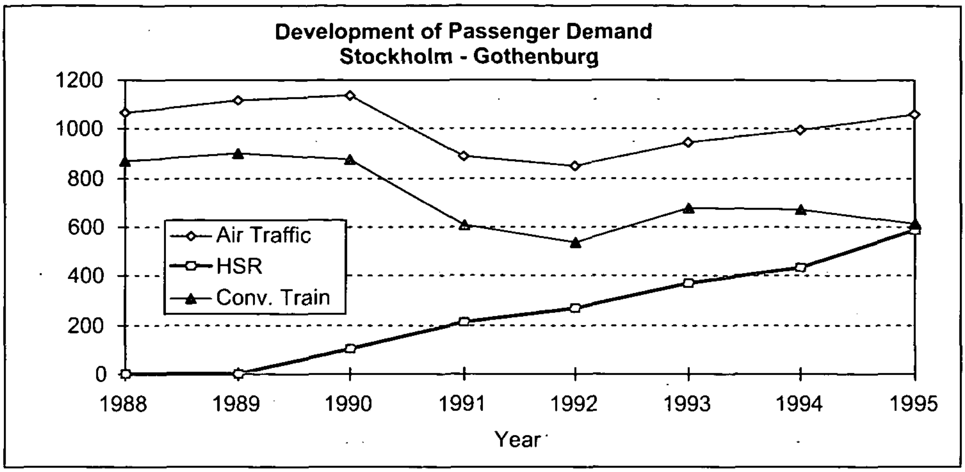

Figure 22: Demand Stockholm-Gothenburg

Development of networks

Looking at the development of APT one can recognise that in the beginning national routes and connections between the big international centres London, Paris and Frankfurt were in the forefront. Exactly these cities are today forming the core of a future European high-speed network, the P/LBKA-line. In first instance national single routes between national centres were in the limelight, nowadays the emphasis is more on connecting these sections reticularly.

Comparison of travel times

In the competition between rail and air, the rail is loosing its advantage on longer distances caused by the higher travel time. Therefore the market share of rail is getting smaller on links with growing distance. Although the market share of rail on relations like Madrid-Berlin or Lisbon-Copenhagen will stay very small as compared to the air market share, the rail is competitive on routes like Paris-Lyon or London-Paris (Fig.24).

The big metropolitan areas will most benefit from the extension of the trans-European HSR network because the high transport demand potential of these centres form the foundations for a high quality service and a competitive supply. Beside the cities London, Paris, Amsterdam, Frankfurt, Milan and Bologna also less important cities can increase their competitiveness with a connection to the HSR network, in particular if they do not have or have only a bad connection to APT (only a few destination or a few frequencies). Long distance trains can, depending on passenger volume, stop at medium connecting stations; special regional trains should feed these railway stations from the peripheral regions.

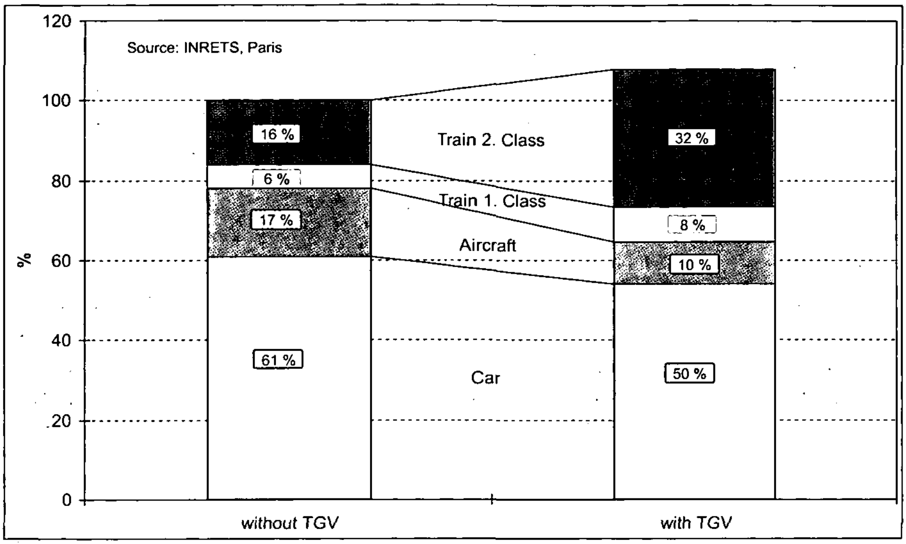

Figure 23: Influence of TGV on Modal Split (Model Calculation by Corridor)

On APT routes, where also high-speed transport exist one can see, that on connections with rail travel times up to 3.5 hours the number of air passenger decreases (Fig. 21). If the rail travel time is higher than 3.5 hours the number of air passengers does not decline but continues to develop as in the situation without high-speed.

1.6.5 Is Air Transport a Forerunner for High-Speed Rail Transport?

Technical features

Lightweight construction: Concerning the development of vehicles, reducing the weight [19] is of importance not only for rail but also for air transport. This can be realised by intensified use of synthetic materials which already play a big part in aircraft construction (e.g. the tail unit of an Airbus A320 consists entirely of composite material of carbon-fibre). Nearly the entire motor train set of the ETR 500 consists of Kevlon. Light vehicles require less energy for propulsion, since the ratio between pay load and empty weight is improved. Savings can be attained by the technical improvement concerning the maintenance because the use of electronic equipment at the power and control systems was taken into consideration at the design of the requirement for maintenance of vehicles.

Safety, reliability and availability: Safety, reliability and availability are already usual in air and rail transport. High safety standards require special systems for diagnosis, communication and maintenance which already correspond to the requirements of APT. Besides the application of flame resistant materials the use of fire alarm systems are standard in the ICE as well as in aircraft. The improved maintenance leads to a higher availability.

Higher comfort [20]: By building new vehicle structures (honeycombed structure) the vibrations during the ride should decrease, which influence comfort positively. New or modified rail vehicle pressure-sealed wagons were constructed to resist sudden internal pressure changes when trains pass each other or enter tunnels at high-speeds. It is not possible in contrast to aircraft, to obtain a totally pressure-sealed wagon with reasonable financial expenses, but the tightness comes close to that of aircraft. Good proofing against sound and heat is achieved by gluing the windows (two glass windows) exactly with the shell plating. This technique is self-evident in aircraft construction. The relationship to aviation is perceptible as well as concerning variable adjustable seats and flight information and reservation systems. So it is possible to realise comfortable travelling together with optimised seat capacity. For offering the passenger short travel times with high comfort the vehicle of a high-speed train, like the ICE, is built as an empty frame, which according to the need can be supplied with sections, open-plan-wagons, restaurants or other equipment. In contrast to aircraft, rail transport sets a high value on offering much space.

Crash test and control systems: Crash tests are standard in the motor industry. Active control systems should prevent crashes, similar to the flight control by air traffic control. The adoption of an automatic vehicle identification system in HSR transport is common use in aviation (secondary radar).

Flexible application: The adoption of the concept of half trains should lead to a higher efficiency in HSR transport. A higher load factor can be obtained by joining or dividing half trains at ramifications and junctions. Thus a higher flexibility and a better adaptation to the demand can be achieved. The interior equipment of the central section is based upon the multi class concept, similar to aircraft. So it is possible to have a flexible creation of the passenger cabin with a standardised basic foundation. Additional attempts are rolling stocks with two decks, like the TGV-Duplex for solving the problem of high traffic volume. The idea of the double decker has its origin in rail transport. At the beginning of this century the railway was equipped with trains with two decks. In 1969 Boeing has built its B747 and there are actual planning for aircraft with complete two decks. The TGV-Duplex exists since 1995.

Balance of energy: For achieving a low environmental pollution, vehicles are in use with a low power consumption. This can be reached with light weight construction, an aerodynamic shape and/ or by optimising the traction performance. In contrast to aircraft where new techniques make it possible to have lower fuel consumption together with a higher performance (e.g. B737 600-800 with the engine CFM 56-7-Turbofan is supposed to have 10% higher performance and 8% less consumption in comparison to the predecessor), the introduction of HSR transport first of all lead to an increase of power consumption. With the development of the ICE 21 a reduction of costs, an improvement of the balance of energy and of safety standards should be achieved. The engine unit of high-speed trains produces high losses of heat that will be emitted to the environment by complicated cooling systems. It has to be analysed how a heat regeneration can be used. In aviation hot exhausts are used by hushkits for an increase of performance.

Organisational and market aspects

A forerunner function of APT can be recognised in the development of the form of company. In European APT for a long time each country has had only one national carrier. These monopolies have dissolved in the last years. Several carriers have been established and are offering scheduled traffic. In Germany the former national carrier Lufthansa has been privatised. In former times there were only bilateral negotiations concerning the first and third/ fourth freedom between the different countries, which exclusively took the national carrier into account. Nowadays the liberalisation of APT is completed. Thus it is allowed to all European carriers to build up routes outside the country of registration in another EC-country. Similar trends can now be observed in rail transport; as jet railway companies have national monopoly positions in rail transport and are nationally owned. Only a few years ago the privatisation of the railway company in Germany has begun. Different parts have been separated from the unit Deutsche Bahn and have been transformed to a joint-stock company. In future also private railway companies should be able to use the infrastructure, that the Deutsche Bahn AG still use exclusively. Within the framework of the EC-liberalisation also foreign railways can operate on German routes for their own profit. Therefore competition will develop, which already exists in APT.

Concerning the comfort at railway stations for HSR transport the same level should be obtained which is already standard at airports. There are similarities between HSR transport and APT referring to reservation and graduated prices for the different day times.

1.6.6 Conclusion

Extensive studies concerning air and rail transport show, that APT and HSR transport are sometimes competitors but often complementing partners, depending on rail travel time. Each of them has particular advantages and disadvantages and operates on specific markets. Although HSR transport has similar travel times on specific national or European routes as APT, it is not able to replace APT. HSR transport is commercially feasible only on city-pairs with high passenger volume.

Beside the transport of the O-D volume (Origin-Destination) rail transport is able to take over a feeder function to the big airports. To guarantee a short check-in time railway stations have to be located at the airport terminal. For that reason there must be an organisational co-operation between air and rail transport, i.e. the schedules must correspond with each other and there should be a similar standard of service. Additionally mutual paying and reservation conditions must be possible.

APT already occurs between city-pairs with high passenger volume, so with the opening of HSR transport on these links the number of flights can be reduced, especially for airports that have capacity problems, but HSR transport is not able to replace APT completely because there are always passengers who prefer in case of connecting flights or for other reasons short- and medium distance flights.

The development of APT started with national routes (Fig. 7 and 8) and the connection of principal urban areas like London, Paris or Frankfurt. Exactly these cities represent the main points of the central future European HSR network, the P/LBAK-line (Paris-London-Brussels-Amsterdam-Cologne). While first of all focusing on domestic routes between national main cities nowadays these sections should be interconnected in a network.

APT in Europe has a forerunner function for HSR transport referring to the development of vehicles, services to passengers, design of future terminals, graduated price policies and the development of the form of company. Essential knowledge of the development of APT -and especially the technical development of aircraft- are for the benefit of HSR transport and can help to save costs and to avoid mistakes. The development of the network depends on the spatial distribution of agglomerations, that means, the networks are the links between the agglomerations (Fig. 5 and Annexes 15,17 and 18).

1.7 Are there Limitations of High-Speed Rail in the Future?

As this hypothesis was created in 1990, a different situation to the present time existed in which the investigation of this hypothesis has been started and many delegations made different interpretations of the hypothesis. Therefore, a careful interpretation on the wording

high-speed rail transport is enjoying its best time,
but its development is limited in the future

seemed necessary, in order to find the best reference scenario about the future of HSR for our work.

This hypothesis is seen from different points of view, according to the delegations who have prepared particular contributions which content several aspects of the wording on Hypothesis 2, especially on the issue about "best time", "limitation in the future" and „high-speed rail".

1.7.1 „High-Speed Rail"

Starting with the question of which field is precisely covered when speaking of „high-speed rail transport", the main question is probably arising from the fact that, according to the maximum speed threshold one considers, huge differences of commercial speeds may result, far beyond those existing indeed between short-distance air services by propeller aircraft and medium-distance air services by jets. The problem is even made more complex if one consider in addition the inclusion or not (or under which conditions of relative part of the high-speed network) of extensions of high-speed services on conventional tracks, and the different possible situations concerning the average distance between consecutive stops.

If in particular we consider extensions of high-speed services on the conventional networks as part of the HSR transport, this may well come to a situation where there would be a unique rail network with a wide range of services, from conventional services on tracks with severe speed limits on O-D with lower demand, up to HSR on dedicated tracks on O-D with high potential, through intermediate solutions including tilting trains.

This would mean that HSR as a «plane on tracks» is still a valid concept for the existing «new lines» and probably a lot of others in the future, but not necessarily at the scale of a full network at the European level for which the average level of service at least according to the speed criteria (or preferably door to door time criteria) could remain significantly lower than the one provided by APT.

Another way to deal with the definition problem could be to give to rail transport a high-speed label everytime rail speed is by far ahead of other ground transport modes, including pure conventional rail. In that case, the classification of a given performance could be different according to the length of the O-D considered, the national or international character of the relation etc.

1.7.2 „Best Time“

Then appears the notion of «best time» that could be considered as the more ambiguous part of the sentence. It is first dependent of the group the viewpoint of which is considered in this sentence. The best time, seen from the consumers perspective, is perhaps when the system has its „maximum“ extension. The best time, seen from the construction companies' perspective, is probably when the infrastructure construction is most intense. The best time, seen from the airways perspective, was probably before any HSR was built. The best time, understood from the global society point of view, should be the period during which the socio-economic profitability ratio of additional projects keep overpassing a target ratio.

It is also dependent of the reference period. If we consider for instance the criteria of the degree of extension of the network, when the hypothesis was formulated in 1989 at the start of the COST Action, no HSR-link, except the TGV Paris-Lyon, existed, and therefore, the hypothesis would have been refuted. At the beginning of the 90s, a "little" network effect has begun in France by several TGV links (Sud-Est, Atlantique, Nord) with the "by pass" in the Paris area. At that time, other countries put also some HSR-link into operation, but no real HSR network has been built up. So, the "best time" was still to be expected. Nowadays, the development of the network has improved, but is still far from being completed, and so on.

If we consider a broad concept of «development value» (could be network length, quality improvement of rail transport, commercial speed, investment opportunities, etc.), a possible «turning point» of the development curve would be of course the moment (at present expected to be year 2010 or 2015) when the major part of the Trans European Network of the European Union will be built (see figure 25 underneath).

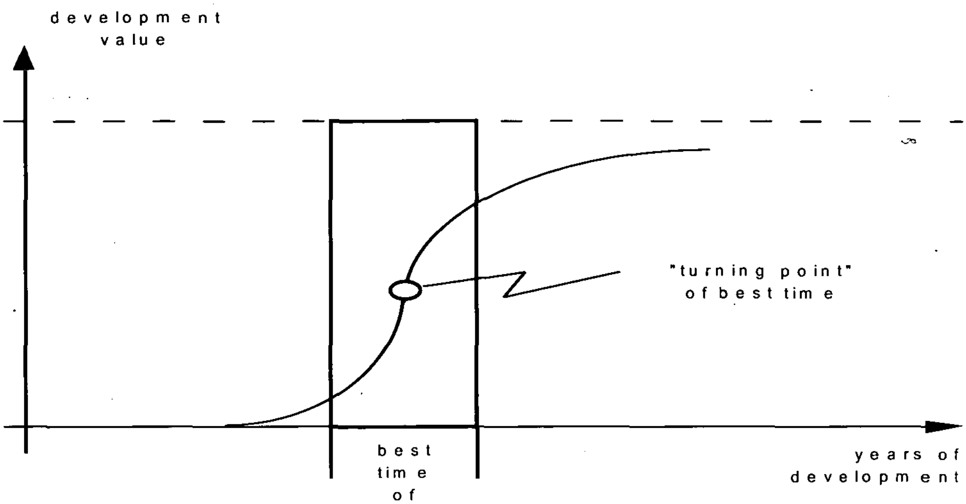

Figure 24: Development Curve

1.7.3 Concept of Limitation

The third important area of uncertainty of the wording of the hypothesis is, as mentioned above, the concept of limitation. There, several possible dimensions of the limitations should be considered.

From the viewpoint of the degree of limitation as compared with other modes, it is clear (see Chapter 2.2 and 3.4 especially) that the limitations are much more on the side of air than of rail for environmental and congestion reasons. Indeed, at some major European airports, where extension of the infrastructure at their location is hard to see, relieving operating measures may make sense for some time, but not solve the problem per se.

The substitution of short-haul (non-profitable) APT by rail transport appears from this viewpoint quite necessary, in order to free capacity for long-distance air traffic development. Moreover, in such countries like Germany, opportunities can be identified for new airports outside agglomerations, airport ground access being provided by HSR connections. As a whole, air passenger transport and HSR have to be seen this way as a single transport system, each system-part (HSR or APT) relying on its own strengths and complementing each other.

But this relative advantage of rail do not mean that rail is free from limitations in the competition with air. The two main ones are strongly highlighted in the report (see Chapter 2.1 and 3.3 respectively) :

- the potentially significant substitutional function to APT lies not over the 800 km range, travel cost and time savings ratios for users setting a limit to the HSR travel distance;

- HSR development, because of higher investment costs as compared with rail, is mainly expected for relations between cities with a high transport potential demand, unless smaller cities without regional air services provided may be included on the course, enhancing HSR profitability and promotion. This is in addition a condition for being able to provide frequencies numerous enough, so that travel time shortening by high-speed is not too much reduced by waiting time at the beginning or at the interchanges.

Besides, some more limitation could come in the long-term from the operationalisation of new technologies, such as magnetic levitation on specific O-D with strong potential of high contribution customers with limited need of connections beyond the O-D served.

The coexistence of conventional and HSR networks, already mentioned when considering the right definition for HSR transport, has also ambivalent effects in terms of limitation.

On the one hand, high-speed is a chance for rail to enlarge its network effect by a higher capacity and by improving the commercial speed thanks to the high-speed segment of any relation in order to guarantee the rail's future on short and middle distances in comparison to aviation (which in Italy for instance got since the 80s more than 13% increase per year instead of a non-increase of rail passengers during that period).

But on the other hand, high-speed has a clear competition effect on conventional services operating on the traditional rail network, so that it makes the situation of railways companies difficult, whereas the problem did not occur for toll motorway network in so far as «national» roads were free for users and a hundred per cent publicly funded.

The drawbacks for high-speed rail development are all the more severe, as compared with the past, as :

- the economic context, although the present crisis may have a short-term dimension not mattering all that much at the time scale of network building up, is not as favourable as the industrialisation of the second half of 19th century for conventional railway network, or reconstruction of Europe after Second World War for motorways, or «trente glorieuses» for air travel expansion,

- the competitive challenge of other modes to high-speed rail (including road for short-medium distances) is incomparably higher than it was the case for previous networks, because of « objective » characteristics of the other networks and of the effects of deregulation.

Indeed, discussions on the (economical) opportunity to build high-speed tracks emerged in the recent past, for instance about the TGV Est (Paris-Strasbourg) where the intern rate of return is quoted 4%, much below the 8% set by the SNCF to be satisfactory (which illustrates the strategic character of the depreciation rate).

It will be of major interest, in a context where the conditions required for public support in the context of the European Union give more constraint to national bodies, to check whether free access of rail companies within the EU, for which HSR will be leader for international operation, in order to receive a real competition, will help to reduce further deficits and subsidies.

1.7.4 Conclusion

Considering all these different factors, it appears quite impossible to give a unique answer, either positive or negative, to the hypothesis.

There is no doubt that there is a high potential for development of high-speed rail in the future. But determining the very moment of the best time, or the relative influence of the limiting factors, is too hazardous and this is more a matter for scenarios construction.

However, this do not prevent from having in mind the main parameters described above when treating the other hypotheses in the following chapters.

2. NEW HIGH SPEED SYSTEM AND OPTIMISATION OF THE ADJUSTMENT BETWEEN SUPPLY AND DEMAND

2.1 The Ability of High-Speed Rail to compete with Air Passenger Transport

The ability of HSR to compete with APT has been clearly evidenced from the very first experience of the Paris-Lyon corridor. From the surveys carried out in September 1981 and September 1984, it appears that the high speed train had a considerable impact on the modal split, increasing the rail share from 40% to 72% between Paris and Lyon, and from 28% to 52% on the overall links between Paris region and the South-East.

If the air market share collapses consequently from 31% to 7% as a whole, huge differences exist according to the types of flows: the decrease by 75% for relations between Paris plus its inner belt and Lyon plus the département du Rhône contrasts with the 15% decrease between the outer belt of Paris and Lyon, and even more with the 30% increase between Paris region and Provence. Clear sign that competition ability is not only a matter of technical performance of the long distance mode, but also a question of relative total duration of the journey, both in terms of distance and conditions of access and egress. In addition, the competitiveness of high-speed train do not prevent the air traffic from a further growth : as soon as 1985, the trend of air traffic between Paris and the South-East of France was becoming positive again.

The experience of the TGV Atlantique largely confirms this initial statement. Surveys have been carried out in September 1989 and September 1993. They show that for business traffic, the air traffic between Paris and Nantes (HSR travel time: 2 hours) decreases by 70% whereas rail traffic increases by 160%, in a general context of strong increase of the total mobility. This shift from air to rail is particularly spectacular among Paris region residents, which mostly used APT prior to the TGV. It affects primarily journeys without overnight stay, and journeys with commercial purposes.

On the contrary, between Paris and Toulouse (HSR travel time: 5 hours), the introduction of HSR services do not prevent the rail business traffic from a decrease by 58% although air business traffic increases by 45%. As a consequence, air traffic, which already had a dominant market share of 73% in 1989, becomes nearly monopolistic in 1993.

French cases are by no means the only ones to illustrate the ability of high speed rail to compete with air. In Spain, on the Madrid-Seville corridor, the respective market shares of air and rail have moved from 14% and 13% in 1990 to 9% and 41% in 1994 due to the introduction of AVE services on this corridor. In Germany, after the introduction of ICE in 1992, the increase of the rail market because of air diversion has reached 25% on the corridors Frankfurt - Hanover and Frankfurt-Hamburg (but only 13% on Frankfurt-Munich and 4% on Frankfurt-Stuttgart, because of shorter distances).

The impact of the Eurostar services through the Channel Tunnel on the traffic of Ile de France residents to London adds to this inventory an international case. From the panel recruited to follow up the effects of the north European HSR, the corresponding air market share has evolved from 72% before the opening of the Tunnel, to 39% during the first year after, the rail market share moving from nearly nothing to 32,5%.

2.2 How to improve the Co-ordination of Rail and Air Transport System Capacities due to HSR Transport

2.2.1 Findings from existing Studies

The approach followed within the group has consisted in focusing on interactions between high-speed rail and air, not dealing as such with effects that are internal to each modal system. This means that such matters as the capacity management of mixed rail traffic (conventional fast trains and high-speed trains) on non-dedicated tracks, or the optimisation of the sequence of aircraft movements according to their size, have not been addressed.

This being granted, it has been considered that the contribution of high-speed rail to a better utilisation of air and rail system capacities can be of two kinds:

- introducing high-speed rail competition where air capacities are congested, with a possible secondary effect on rail congestion,
- enabling connections between air and interurban rail services more convenient for travellers.

In the first situation, the major effect is to divert from the congested airport(s) a part of the traffic corresponding to O-D served by high speed trains, so that airport(s) traffic will be released from aircraft movements which may be for a part frequent and low capacity ones. In addition, planned investments on conventional tracks, because of some collapse in the near future between the needs for freight and passenger trains, or for suburban and interurban trains, could be avoided.

In the second situation, the effect would be to replace feeder flights connecting with long-distance flights, by high-speed „feeder" trains benefiting in the optimal case of direct connections at airports and compatible time-tables. The consequence would be to increase the relative availability of airport slots for taking off or landing of long distance flights. Speaking of better co-ordination between air and rail looks appropriate only in this second situation.

The group has consequently tried to inventory and analyse the main studies developed in the participating countries as well as at the European level dealing with such situations. It has especially considered the three Dutch studies refereed to as PASO, IEE and high substitution scenario studies, the three French studies dealing with the impact of TGV Sud-Est, Atlantic and North, the Italian study about the corridors Milan-Naples and Turin-Venice, the three Spanish studies applied to the corridors Madrid-Seville, Madrid-Barcelona and Madrid-Lisbon, and the three international studies launched about the PBKA project, the European scheme for HSR and the Lyon-Turin corridor. A synthesis of the main findings from each of these studies appears in Annex 14.

Indeed, it appears that almost all the studies available deal with the problem of the impact on the volume of the market and its modal split of new high speed lines. That means that the problem of utilisation of capacities can at present only be addressed in terms of air/rail competition on specific corridors or networks, and not in terms of complementarity between air and HSR networks. The „co-ordination“ dimension of the hypothesis consequently cannot be treated properly on this basis.

Secondly, the information available about the studies considered is quite variable, both in terms of description of the context, kind of results produced and indication of the methodology used. Consequently, a full comparative approach would require a much more in depth-analysis of each study.

Bearing in mind those limitations, it is nevertheless clear that the comparison of the results of those studies shows a huge variety of impacts of high-speed rail on air traffic. The main factors are probably the time of journey with HSR, the initial modal share of air services often correlated with the distance, and the structure of the demand, especially business/non-business, without forgetting the strong influence of supply attributes such as fares and frequencies. In addition, a similar impact on air traffic can produce very different contributions to a better allocation of capacities, according to the level of congestion at airports for the cities considered, and to the proportion of O-D served by high-speed train in the total traffic of these airports.

2.2.2 New steps forward

On the basis of the studies mentioned above, a specific effort has been devoted at reaching a better understanding of the differences of results between the various national or European studies. Diverse reasons can explain differences in forecasts :

- non comparability of projects considered in terms of key parameters such as distances between main stops on the network or average commercial speed,
- differences in the context that surrounds the evolution of the transport supply, and that may have a stronger influence on mobility behaviour than the transport system itself,
- differences between the hypothesis introduced in the scenarios, for instance concerning the absolute increase in prices or the fare structure,
- differences in the structure of the models, leading to various ways to take into account or not each possible factor,
- differences in the surveying methods by which the dates used for the calibration of the model are produced
- gaps between the national behavioural responses to a given change in transport supply.

An ideal situation would be to establish a typology mixing the two first reasons so that each type would be homogeneous enough in terms of transport and context conditions, and then to estimate the impact of the choice of a type of model for a given set of scenarios (identical hypothesis for each variable), so that the remaining gap could be attributed to real differences in behaviour.

But a range of factors prevent from reaching this ideal situation, such as inconsistency of types of transport context because of too poor sample of studies available, or practical difficulty to re-estimate results by changing the hypothesis introduced in a given model and reprocessing it.

Consequently, we have focused on the understanding of the capabilities of the different models used, assuming this was the most critical area for any further attempt to compare results. Within this general target, a particular attention has been given to the treatment of the substitution/complementarity alternative, considering that most attention has been devoted up to now to competition between modes, and most models calibrated on data reflecting this kind of situation, and that it would so be worth knowing how models could in the future better take into account scenarios of complementarity.

To reach this target, a seminar has been organised in June 1997 (see program in Annex 15) producing a confrontation between some of the best experts involved in the studies described above. From the ideas arising of this seminar, a special paper, to which a questionnaire was attached, has been produced with the help of a specialist of models, Marc Gaudry. This package was addressed to researchers having a major experience in the field, have they participated in the seminar or not, so that they would have a real opportunity to explicit the specifications of their model and their opinion on the problematic proposed.

From the answers to the questionnaire as well as on the basis of the papers currently available from the authors, a paper has been produced and submitted for validation or criticism to the initial recipient of the questionnaire. The final version of it, taking on board the remarks from modellers, is reproduced in Annex 15.

A first possible statement is that all models considered contain line complementarity, i.e. they are able to combine links belonging to pure modes in such a way as to define paths or alternatives. This is typically the case with public transport modes requiring access and egress, models taking into account this situation.

On the contrary, it is not clear whether models, except the French MATISSE model of INRETS that allows for some scheduling complementarity, include the kind of complementarity that would result from the definition of alternatives at some stage (service/carrier/schedule, or mode, or destination/mode) in such a way as to allow cross-effects of the same sign as own-effects to arise. However, for instance, in the Dutch ILCM model from HCG, the air route choice model contains utility elements of the TGV mode, so that an air/HSR connection would result in an increase of the air utility.

Alike, none of the models, except the German QDF model of BMV for origin/destination pairs, allow for cross-effects of the same sign as own-effects in the determination of the frequency/destination levels or for given, or transport-condition sensitive, activities, unless they use accessibility indices.

Considering now gross complements, defined as modal demands affected in the same direction by pure link modifications, it seems that no model yield them, the induction effect being generally insufficient to transform substitutes into complements.

The amount of substitution (or complementarity) obtained in the share component of most of the models, depend upon asymmetric responses of the share or probability curve resulting from non constant marginal effects of changes in travel time, frequency or other modal characteristics. This is typically the case for models using log-normal distribution of values of time, Box-Cox transformations or significant segmentation.

It is more difficult to assess which forms of the models determine the absolute level of demand, in so far as they tend to be non-linear and predetermined, as well as applied to a few terms like population, without an explicit intent to capture the form of the induction effect.

This analysis would be incomplete without mentioning that specific features affect transportation models, and in particular the measurement of diversion. The main ones probably relate to the degree of aggregation of key parameters like space (through the zonal system), trip purpose and « moments» according to which the values of the service levels are supposed to vary, which determines the location of centroids. Another common feature in transportation models is the degree of modal captivity, although it could to a certain extent reflects the modeller ignorance about appropriate factors.

As a whole, although the too limited number of answers to the questionnaire does not allow at the present stage for commenting upon the variability of modal, total and share elasticities according to the various types of models, there is little doubt that all of them only exhibit gross substituability, and not gross complementarity. But, as mentioned above, this could well be the consequence of a market situation where competition has by far away the lead on complementarity, rather than the result of a lack of capability of the models themselves.

This being granted, a more precise comparison of the models appears compulsory in the perspective of a two-fold objective :

- understanding better the reasons of differences between models in the estimation of the diversion/induction effect in various situations of mode competition, although each of them seems to have appropriate specifications to this respect,
- identifying the most appropriate modelling tools for the test of scenarios of complementarity (see Chapter 2.4), considering in particular the more specific nature of the parameters likely to influence travel behaviour (in terms of compatibility between distinct modal networks and services, beyond the intrinsic performance of each of them).

It is clear that such an in-depth comparison between models would require a strong attention not only to the major modelling options discussed above, but also to the detailed treatment of parameters like the distribution of prices paid by the different types of customers according to their own characteristics, delays of reservation, etc. beyond the precise time and O-D of travel, or the distribution of access and egress, or the level of «comfort» of the transport.

In addition, considering specifically the perspective of developing a modelling approach of complementarity in the future, a direction for further research could be to analyse the possible influence of HSR-air linkages on the development of new activities or on major shifts in activity location.

This means that the initiative of a seminar devoted to the question of models comparability within the COST 318 action, as well as the problematic paper resulting from it, should only be considered as a first step, although hopefully a significant and positive one, in the direction of producing a better comparative understanding of the results of different studies already achieved, and of enabling in the future an appropriate choice of the modelling tools according to the kind of problem addressed.

As a conclusion, it appears from the comparison of the different case studies treated that a significant contribution of high-speed rail to a better coordination and utilization of rail and air system capacities is likely to be effective if and only if certain conditions are gathered, such as appropriate times of journeys by HSR (between two and three hours in present conditions), a high potential of traffic (especially for business purposes considering the average structure of air demand) between conurbations served, and at least one of these suffering from air traffic congestion.

To go more in depth with the assessment of the impact of high speed rail according to specific contexts, it would be very helpful to extend the process initiated by the COST 318 seminar on modelling in the direction of a better understanding of the differences between results derived from various studies. This could be achieved through the constitution of a working group benefiting of a more widespread participation of experts in the field and of a time schedule allowing for successive interactions among them, including some additional modelling on a totally comparable basis.

2.3 Are there Improvements in the Distribution of Air Transport Demand among Airports?

2.3.1 Distribution in general

As experienced,"high-speed rail transport is able to compete successfully with APT demand" (Thesis 1); not only due to commercial high-speed (see definition on Annex 16), but also due to attractive fare structures compared to O-D air fares in the range where air and HSR transports are competing[15], this because rail transport in general is able, even per transport unit, to supply high volumes of transport compared to other modes. This helps to keep transport unit (seat) cost down, even if high-speed rail transport, as defined within the Action COST 318, needs new infrastructure, mainly as new tracks or at least improved classical tracks, meaning a significant impact on infrastructure costs.

15 See ITA-study. Air fares when connecting at airports may still be (much more) attractive, as air feeder services may be at no cost for transfer air passengers;

The saving of travel time by a rail transport being able to achieve commercial high-speed[16], the necessary adequacy of high passenger traffic demand with high transport volume capabilities by rail, in order to keep transport unit costs down, leads to the consideration that HSR will be built to link high passenger traffic potentials: that are first agglomerations[17]. High passenger traffic volumes are also to be achieved on trunk sections when merging several lines in the same general direction[18].

Being the junior system, HSR is the "challenger" to APT on links where they are able to compete, or complement each other [19]. The question arises whether

"high-speed rail transport allows a better distribution
of transport demand among airports"
(Hypothesis 4),

not only substituting passenger traffic from air to rail transport[20], but by a better use of (medium-sized) under-utilised airports, having their catchment areas increased by a (much) better ground access provided by rail, thanks HSR[21] (and relieving APT congestion at major (hub) airports).

The hypothesis wording ***suggests*** [22] that:

1. air passenger demand could be distributed in another way that the one taking place actually;
2. there is a need of a better distribution of air passenger demand among (more or less close) airports, and
3. HSR (airport rail stations) are beneficial to this need.

The need of a ***distribution*** and of a better ***one has to be related to those involved***, that is the points of view of the users (air passengers), operators (airlines, railways), (airport) authorities and general public (tax-payers, immission areas).

16 Having to reach high-speed makes the use of HSR in urban areas not convenient, as urban networks need many network access stops;

17 For instance Paris-Lyon. That does not mean, that "on the way between" some local communities may not benefit from the close HSR line (such as Vendôme (about 20.000 inhabitants) on the TGV-Atlantique; or even Ciudad Real & Puertollano (about 50.000 each) on the AVE line Madrid-Sevilla).

18 For instance between Le Mans/St. Pierre des Corps and Paris, access to the high-speed line being provided by the classical rail network from Brest to Bordeaux and beyond (TGV-Atlantique). Even the Paris-Lyon high-speed line developed as a trunk line when considering the TGV connections between Paris and the destinations beyond Lyon (TGV Sud-Est network);

19 Instead of air feeder services;

20 On some heavy O-D links, such as Paris-Lyon and Paris-London.

21 Such as Lyon-Satolas;

22 See developments in the paragraphs hereafter, as well as in the Annex 17; see also what 's the experts' opinion (Chapter 4.3 with questionnaire).

Another distribution that the actual one implies that ***there is another airport choice***:

- ***with liberalisation***: this has just been (fully) achieved in Europe (third EU-liberalisation package);
- ***with*** (much) ***better*** (time-related) ***ground access***;
- ***within an agglomeration***: this will be more the case for the larger European agglomerations where there are (or there is the need for) more than a single commercial airport to be run;
- ***between agglomerations, especially as HSR is concerned***: this will be especially the case where airport catchment areas overlap;

This is not always the case for air passengers having to take their plane from their living or working place in agglomerations (excepted in Europe in the biggest ones). Most of them would keep preferring to fly from an airport of the agglomeration or of its close neighbourhood. But for people living or working in places between agglomerations, and so, between commercial airports of relevance, there is (at least a theoretical, but at the best a real) choice between airport gateways, according to access time, place, flight, time of departure (and arrival).

The airlines are facing cost-cutting programmes in order to improve their competitiveness and profitability. Seeking concentration at their hub airports, at least at their home bases, could make sense, if the resulting loss of customers (and revenues) at other down-scaled airport operations is matched or at least affordable.

The authorities, those responsible for the airport management and development are keen to defend the interests of their airports (and the region) against the effects of competition, now enhanced (within the EU) by liberalisation and privatisation, and are eager to boost as far as possible air traffic quality and volumes, trying to match cost swellings by increased revenues. Doing so, they will keep trying to keep or whenever possible to increase their share of (transfer) traffic (as a hub-and-spoke platform) and, doing so, seek for concentration and complementarity from other means of transport, in order to enlarge (by HSR) their own catchment area and to improve feeder services.

But they will have to take into account general public opinions: a concentration at airports is generating more concentrated noise and air pollution (an environment issue for sensitive people), more costs and investments (for taxpayers), even if it is to be balanced with more workplaces (as efforts against unemployment).

Compatibility as "complementary" and/or "by substitution"

The hypothesis wording implies first that there is a ***compatibility*** for users between air and rail (passenger) transport. This compatibility can be regarded as ***complementary*** between the two modes of transport, or as the ability to choose one mode in preference of the other mode of transport, which will be called ***by***

substitution. This is mainly the case of a (new) challenging service, such as high-speed rail links between airport areas[23].

From this historical point of view, there is already a compatibility, i.e. a complementarity by substitution, to be found between air and rail passengers transports in Europe. This has also been underlined in outside reports[24], particularly where 3 distinct ranges are cleared up, specifying the influence of air and high-speed rail transport on each other:

- „1st range: until 350 km travel distance (as the crow flies): high-speed train advantages dominate by far;“
- „2nd range: from 350 km to 1'000 km travel distance (as the crow flies): high-speed rail and APT compete;“
- „3rd range: over 1'000 km travel distance (as the crow flies): APT dominate per saldo;“

In this respect, complementarity is defined as follows:

"Two modes of transport will be regarded
as complementary for the user
when their successive utilisation
is either necessary or simply preferred to the utilisation
of a single transport mode for a journey between two cities";

focusing on the successive utilisation of high-speed train (as feeder, i.e. substitute to air feeder services) and APT (on distances where even high-speed train is no longer competitive) resulting from the addition of a part distance within the 1st range (where high-speed rail transport dominates APT) and a part distance within the 3rd range (where APT dominates high-speed rail transport).

2.3.2 Past and present Distribution of Air Passenger Transport Demand

Let us consider first an anecdote of the past, as weather conditions played a major role in Europe in air traffic operations and as airports had to be closed and flights re-routed due to bad weather condition. Distribution of air traffic among (still open) airports took then place, even if this was not quite according to the users' transport demand. Nevertheless a re-routing and a landing (at a close) airport, such as Basle instead of Zurich, was regarded as better than the cancellation of the flight.

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23 See Chapter 1.2 "Tendencies in the world around HSR and air travel";
See short mission report to AdP, Aéroports de Paris, estimating *air traffic loosing* (Annex 43):

- 70 - 80% by 2 hours travel time between 2 agglomerations;
- 20 - 30% by 3 hours travel time between 2 agglomerations;
- 10% by 4 hours travel time between 2 agglomerations;

24 See ITA-study: on behalf of the EC Commission and carried out by ITA, Institut du Transport Aérien, Paris, on "Rail/ Air Complementarity in Europe; the Impact of High-Speed Train Services"

This should point out, that even an imposed distribution is better that none, provided that the (ground and air) system works.

Air traffic distribution among airports exists in some European agglomerations, like in London (Heathrow, Gatwick, Stansted and Luton), Berlin (Tegel, Tempelhof and Schönefeld), Paris (CDG, Orly and Beauvais) and authorities are/were in grade to allocate air traffic from airport case to airport case[25], for instance according to:

- the ***mode of operations*** (freight; charter flights, i.e. leisure traffic; scheduled traffic; general aviation);
- the ***specific airport*** (night ban, aircraft movement ceiling; congestion (slots); (STOL-) aircraft type capabilities);
- the ***involved*** airlines & nationality outside the EU (according to ***bi-/ multilateral agreements***, reciprocity rights, policies), the involved type of traffic, customs and security regulations (EU domestic market). This will generally be justified by the authorities, according to their tasks (management, overall organisation, operations, the ability to provide the required facilities; cost-cutting programmes, optimal utilisation of the infrastructures).

Distribution as "free" or "imposed"

We also have to have a look at the situation where ***distribution of transport demand among airports*** is ***free*** or ***imposed***, as, notwith-standing the fact that liberalisation in transport is coming, we have to deal within Action COST 318 with the present background in rail and APT.

A free distribution among airports may be achieved by a free airport selection[26] by users' and operators' choice according to market conditions. The EU commitment to APT liberalisation is expected to enhance this aspect. One main working condition

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25 Airport operations are distributed in London at Heathrow (mainly for scheduled flights of airlines with grandfather rights), Gatwick (for BA leisure traffic shifting from Heathrow- to Gatwick-airport as with leisure air traffic there is a reduced risk of loosing of intraline-transfer traffic), Stansted (for those taking the opportunity of being close to the North-East region of the agglomeration), the City airport (for STOL-operations), Luton (home base of two main charter companies and taking the opportunity of ground access from the North of England). In Berlin the role distribution comes partly from environmental purposes and the former political distribution with Tegel as main player, and like Tempelhof (for regional airlines only) most central, and with Schönefeld at the outskirts, which future role has been promoted. In Paris there are mainly CDG and Orly, but also the remote Beauvais, which commonly plays a helpful role when the big airports are on strike. Even Oslo had the commercial air traffic distributed between Fornebu and the farther Gardermoen airport for charter operations; and Stockholm Bromma airport, very close to the city, remained open for some domestic flights with environment-friendly aircraft (BAe-146)

26 As it is the case when deciding on a (leisure) travel tour, the meeting point will be at the airport of departure. The airport of departure may also be chosen abroad (with a foreign travel agency). On the contrary a current example on a reduced scale is provided by several commercial airports with an agglomeration, for instance between Paris-Orly (Southern part of the city) and Paris-CDG (Northern part of the city), where the vicinity of the airport may play a key role (for business travellers).

therefore is quality of facilities (for operators) and of airport access (for users). It is (at the end) the air passengers' choice.

An imposed distribution among airports may enhance a counter-balance to traffic volume concentrations and be achieved by authorisations (slot allocation) and imposed selections, for instance according to the type of operations (freight; charter, i.e. leisure traffic; scheduled, i.e. business traffic; general aviation (ban); night traffic ban; etc.), whereas activity overlaps may not be excluded)[27]. This was/is the case in Europe[28].

An "imposed" distribution among airports can also be made "passive", by lack of adequate airport access (for the users) and facilities (for the operators), bearing in mind that decisions on investments to up-date and up-grade airports are taken mainly by the public authorities.

A neither "free" nor "imposed" distribution can nevertheless be expected in a free market: due to lack of traffic or cost-cutting programmes the operating airline will have chosen a (sole) "strategic" airport; the air passenger's airport choice will be regarded as "imposed" by the chosen airline; the airline's airport choice will be instead free, i.e. according to its interests (and normally its passengers, but considered as a whole).

Developments within and between agglomerations have to be taken into consideration.

Summing up the kind of distribution (see Annex 17):

- ***"free": means user choice.***

  Each airline on each airport and no difference in (restriction of) operation. The airport choice will depend mostly on user location and ground access facilities.

- ***"neither free nor imposed": means airline choice.***

  Airlines wish to concentrate their operations on one airport for cost-cutting purpose. Airport users have the choice to leave their favourite airline and go to the competitor at the more convenient airport.

- ***"imposed": means authorities choice.***

  The authorities select the operations on each airport. Airport users are told to which airport they have to go to.

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27 For instance authorisations (slot allocation) for the London-Gatwick instead of the (congested) Heathrow Airport. Luton Airport (home base of two charter airlines) mainly influenced by charter traffic. However, "charter"- groups are also to be found on scheduled flights (together with business travellers).

28 But also in a "deregulated" airline industry, for instance at Washington-National Airport, where "wide-body" aircraft are banned.

"better" distribution

It has been advocated, "high-speed trains help eliminate the problem of congestion on some high-density sectors with major origin-destination traffic flows".

If complementarity by substitution from APT is made possible, and the results of high-speed trains show that this is the case, so ***"a new distribution of transport demand among airports"*** has already started, by subtracting from APT demand at airports the traffic volume attracted by the challenging (high-speed) rail services.

All this means a substitution from air traffic to rail, but not necessarily a "better distribution among airports".

Although the kind of new distribution by subtracting a constant amount of air traffic volume (between two considered airports) certainly represents advantages in particular with regard to environment protection and energy consumption[29], but also in increasing the share and capacity reserves at airports for long-haul air traffic, where alternatives at the ground level don't exist in-deed, and may be qualified as "better", this is not the main sense we meant in the hypothesis wording for "better" distribution.

Instead of focusing on a new distribution by a uniform subtracting at (both) airports, we refer by a "better" distribution mainly on a better distribution according to the capabilities of the airport system elements, either by concentration (if the major hubs can afford it, and, at the end, closing regional airports for commercial traffic) or decentralisation (reducing traffic congestion at major (hub) airports, in favour of the better utilisation of existing facilities at under-utilised neighbouring airports).

Summing up, a "better" distribution of APT demand refers to a more preferable one than the one taking place currently when considering the effects involved. Conditions to be met therefore could be aimed at targeting the best use (for users, operators or civil service) of the (existing) transport capabilities, providing a counterbalance or none, to traffic volume concentrations[30].

Need for a "better" distribution of air passenger demand

The need for a "better" distribution of air passenger demand among airports implies that there is another (airport) choice and that it is to come from different points of view on more concentration (relief). It could arise from a subjective ones, but one has to focus on the expected following objective arguments, in phase with the particular interests involved:

29 These aspects are already dealt with COST 318 (in particular hypothesis 6).

30 In the ITA-study, concentration (in Paris) is underlined. On the contrary, saturation worries due to concentration emerge at the Frankfurt Airport, as Lufthansa is considering the setting-up of a second "hub" in Munich.

Aiming at more concentration on existing major (hub) airports and having small- and medium-sized airports down-graded or even being closed:

- ***airport authorities***: small- to medium-sized airports (the majority) obviously can't agree; owners of big-sized airports will agree, provided their airports can be extended; otherwise they will try to attract what suits best to the owners (state, region, communities or private company).
- ***airlines***: especially the home base air carrier will agree, provided feeder services are better than those at the home base of its next (major) competitor; major carriers and (hub-feeder) airlines with small-sized aircraft will agree if they get slots; "hub-by-pass" airliners could agree if small- to medium-sized airports are not being closed to commercial traffic, but are expected to strongly disagree in the contrary case.
- ***air passengers***: concentration could mean for them more frequencies, flights which could not be provided from other close airports, because the airport catchment area or the facilities (runway length) are not large enough. But concentration and huge airport could also mean airport dependency, larger access (distance and) time, long-distance walks in the terminal, delays (at peak time) and fear of feeling lost (elderly people).
- ***ground access***: if by road, concentration isn't a good solution, as airports have difficulties to provide more parking space and parking taxes are increasing. Moreover, existing (major) hubs are located in or close to agglomerations where the road traffic has its daily congested, if not saturated peaks.
- ***general public***: general public as people living in the neighbourhood will have no joy at (more) concentration, which means more noise frequencies and more (concentrated) air pollution (even if specific noise & air pollution emissions per single aircraft movement are decreasing); agreement of the general public as taxpayers is a much more complicated issue, depending on their professional and social identity, their political views and on airport stakes.

Aiming at using (under-utilised) medium- and small-sized airports already existing in the country (and being up-graded) to relieve saturated (major) airports:

- ***airport authorities***: small- to medium-sized airports (the majority) obviously will agree; owners of big-sized airports (powerful minority) will not.
- ***airlines***: especially the home base air carrier will disagree, as the hub-and-spoke system is going to be diluted by "hub-by-pass" links and major competitors get an advantage on a weakened major carrier; regional "hub-by-pass" airlines with small-sized aircraft will agree and try to get slots at destination airport; some of them could be "new" (farther) hubs instead of the "old" (close) one with (only) feeder services).
- ***air passengers***: they no longer take care of the aircraft size and the number of engines to satisfy their need of safety. More air services at small- to medium-sized airports could mean for them more choice in flights, frequencies, fares, as, for many of the potential users, catchment areas of these airports could overlap. Less airport dependency, shorter access by

(distance and) time, short-distance walks and a more human environment in small-sized terminal and aircraft, are on the target for appreciation (elderly people will strongly agree).

- *ground access*: if by road, decentralisation in the access system is a quite good solution; small- to medium-sized airports have less difficulties to provide (for air passengers very) close free parking space.
- *general public*: general public as people living in the neighbourhood will have no joy at being introduced to aircraft noise, although air pollution by small-sized aircraft on an airport should not develop to a serious matter of concern, but people living in the neighbourhood of major airports will (very) much appreciate a (short-life?) relief in aircraft movements. Agreement of the general public as tax-payers is a much more complicated issue, depending on their professional and social identity, their political views and on the airport stakes.

Airport catchment area[31]

Like an hydrological basin, an airport has around itself a local area called airport catchment area, where ground access opportunities make it a "natural" choice when travelling by air.

It is clear that ground access opportunities are not ***influenced*** by topography only, but ***mainly by ground access time***, settled by car ownership, frequent public transport, good (dense) road, motorway and/or rail networks, up to (high-speed) rail stations at airports. This means that areas can be found, where the catchment areas of several airports overlap[32].

As airport ground access time prevails over ground access distance and as access average speed by train is often (by HSR surely) higher than by other ground access modes, the airport catchment area increases thanks to rail access, considering a specific ground access time. Moreover, the catchment area overlap area of two airports, if any, increases, or may appear.

An airport catchment area with ground access by rail is then on a map no longer roughly circular, but ovoid, along rail (access) axes, at least by HSR, that is towards the next urban areas; we have stated, HSR developed first between agglomerations. This is much more the case with a rail station at the airport[33] .

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31 We limit us on ground access (and the to them competing airport feeder services); that is we do not consider the "catchment area" of some airline "hubbing" systems (which are about to work "global");

32 A unique example for someone leaving Neuchâtel (Swiss Jura foot) to attend COST 318 meetings in Brussels: his airport choice will be really among Berne, Geneva, Basle and Zurich;

33 See Chapter 4.3

2.3.3 Trends and Prospects

Liberalisation:

The (multilateral negotiated) IATA world-wide fare system on scheduled flights, a wide range of bilateral agreements (mostly excluding commercial rights of countries not involved in) and the consideration that national airlines ("flag" carriers) are a matter of national politics and pride, just gave a boost at the conception of how, after World War II, APT had to be regarded.

This is still alive, while the EU heads for introducing (full) liberalisation in the airline industry within Europe, being effective with the so-called third package.

Liberalisation in (the EU and in other) parts of world of the airline industry is expected to lead to the fading of "imposed" distribution of APT demand.

The EU tends also to a liberalisation of airport operations within the community of member states. Airport privatisation is also on the agenda[34].

Could we see in the next future a generalisation of airport choice for departure (and for arrival)[35], just like airline choice now.

Concentration; hub-and-spoke systems

Long before it became famous in America just after the Deregulation Act, hub-and-spoke systems were already working in Europe at least at the home base of national carriers.

Transfer traffic has become (very) important[36] for the national carrier of (small) European countries, in order to fill bigger planes on higher frequencies and compete successfully with (even much) larger airlines.

Another effect of concentration is that scheduled and charter flights are no longer separated, as charter groups are carried in scheduled flights.

Will concentration last ? Will there be (more) concentration with (more) congestion (up to saturation) at (big) hubs?

Will the use of improved technology, as well as airport and airline management be able to cope with more concentration without saturation to non-affordable level? For

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34 Has already been tackled by the BAA, British Airport Authorities. In this case, airports (administrations) will be forced to exploit and promote their strengths much better (and, moreover, to cope with their weaknesses).

35 "Open-jaw" return tickets tarifs are coming up;

36 Most airlines want to go to or stay at London-Heathrow, mostly because of the transfer opportunities. This is the interest of BA (about one-third of their passengers at Heathrow are transfer passengers; otherwise at least a part of them would transfer elsewhere, that means also abroad). It is also the interest of BAA, British Airport Authorities, to handle according to the wish of its best customer.

instance, what about London-Heathrow, the biggest airport in Europe within its actual boundaries? What next after the fifth terminal (at Heathrow) has been put into operation?

Are people (taxpayers, airport neighbouring communities) going to accommodate themselves with more noise and air pollution concentration in their lives, given that (lasting) prosperity (in economics terms) is related to the ability of their airport to cope with future competition?

Is it exact that more traffic gives an airport the opportunity to be more cost-effective and (more) profitable? If yes, what a future for medium- and small-sized airports?

Towards decentralisation of air passenger traffic ?

There is already a decentralisation of air passenger traffic by regional airlines in Europe, by-passing the next hubs to farther (hubs) destinations and even providing successful through regional services[37].

2.3.4 Case Studies

Dealing with hypothesis 4 has been supported by the following case studies:

- "AVE" (Madrid- Cordoba- Sevilla);
- "Direttissima" (Milan- Florence- Rome);
- "TGV- Sud-Est before" (Paris- Lyon);
- "X 2000" (summing-up the Swedish aspects);

- **Spanish case study "AVE"** (Madrid-Cordoba-Sevilla)
  (a European case, where the secondary airport is peripheral)

As there are no rail links to airports in the existing AVE area, the experience collected with AVE on Madrid-Seville suits very well to contribute with a case study to hypothesis 4, as in 1995, passenger by HSR traffic on Madrid-Seville was either substituted from other modes or new (see Fig. 12) and remaining air passengers claimed as reasons as on Figure 13.

Apart from a substitution of (O-D) air passenger traffic by AVE between Madrid and Sevilla, which had a very significant impact[38], questions whether a new distribution of APT demand is taking place have been related to the ***access to and from Cordoba by AVE for air passengers incoming or outgoing at the Madrid and Seville airports are,*** one supporting complementary aspect being the fact that scheduled flights no

37 For instance Crossair in Lugano.

38 As a matter of fact and shown in Annex 18, rail passenger traffic volumes increased between 1990 and 1996 by:

- 3.4 times between Madrid and Sevilla; and on the part links:
- 5.7 times between Madrid and Ciudad Real;
- ***2.1 times between Madrid and Cordoba;***
- ***4.9 times between Cordoba and Seville;***

most of the increase taking place in 1992.

longer operate on the Cordoba airport, which is just why it is interesting to see how air passengers in this area have distributed between the Madrid and the closer Sevilla airports (thanks to the AVE).

1. How many air passengers (total for the year or daily on average) to/from Cordoba, including those using other airports ?
2. How many of them are using AVE as an airport part-access ?
   Of which, how many:
   2.1 to/from the Madrid airport ?
   2.2 to/from the Seville airport ?
3. before "AVE" ?

The most relevant answer received from AVE is that "***on average 46 passengers a day are travelling with the AVE to/ from Cordoba and connecting with a flight to/from abroad*** (national flights not considered)"; as "air passengers are using the AVE as an airport part-access", a share (estimate) between the Madrid & Seville airport gates is still missing, as well as the figures (estimates) "before the AVE"[39].

- **Italian case study "Direttissima"** (on the Milan-Bologna-Florence-Rome transport corridor)
  (a European case, where the secondary airport (Florence & Bologna) are located between the main airports of Milan & Rome)

Background of the "Direttissima" case study is the transport corridor Milan-Bologna-Florence-Rome, where HSR ("Direttissima") applies to the Florence-Rome leg.

Link	Passenger per day	No"Direttissima"			"Direttissima" operating		
		Car %	Rail %	Air %	Car %	Rail %	Air %
Rome-Florence	2900	27.9	55.4	16.7	18.7	70.2	11.2
Rome-Milan	4500	2.6	25.0	72.4	2.5	28.0	69.4
Florence-Milan	1800	23.4	74.2	2.4	23.4	74.2	2.4

Table 8: Modal split (in %) to hypothesis 4 (no rail stations at airports)

39 AVE quoting: "As the questions are very important and can be very useful for AVE .... , we will ask more detailed questions to our passengers in the next poll in November. We will have the results of this in January 1998, and of course you will be informed of it." The gate share (estimate) Madrid/Seville Airport is expected at 9 to 1; this ratio will be checked on the next AVE survey, November 1997. One has however to consider, that since AVE is in service, flights to/from abroad at the Seville Airport have been reduced.

Results[40] have been provided on passenger traffic modal split (air/car/rail) and imply "No-Direttissima", that is the status quo ante (by classical trains), and the "Direttissima operating" (see Table 8). Figures on the Rome-Florence link show, that modal split shifts are quite sensitive; there is a competitive effect coming up, as the results provide a substitution (and new traffic) to HSR.

Calculations on a new distribution of APT demand between airports (Florence & Rome) close to the "Direttissima" line, by concentration („Direttissima" feeding the Rome airport hub) or decentralisation[41] of air passenger traffic volumes (see Annex 19) have been provided, but with rail links at airports (see Chapter 4.3). They show clearly, ***according to the simulation results, a (significant) new distribution of APT demand is taking place as soon as congestion, expressed by delays[42] at the major (hub) airport of Rome (FCO), is occurring.***

- **French case study "TGV-Sud-Est before airport rail stations"**
  (a European case, where there is also an opportunity to compare the APT distribution *after* the introduction of HSR rail stations at both airports. This case is being dealt mainly according to the short missions on May 16th 1997 in Lyon-Satolas and June 3rd 1997 with AdP)

Before the TGV system went into operation (1981), the bulk of the air passenger traffic between Paris and Lyon concentrated in Paris-Orly, which was the main airport in Paris for domestic APT (Air Inter "hub"), even if some flights were landing in CDG according to main connection purposes, but at a time where Air France had no dedicated hub-and-spoke system as since Spring 1996.

Substitution by TGV of mainly domestic air travellers occurred on the Orly-Satolas run, as a part of the remaining O-D air passengers might have to do in the neighbourhood of the airports, rather than in the city-centres.

We have said that substitution by HSR of APT demand between two points is not what we first mean by "a better distribution of APT demand among airports", although relieving airport congestion, which is much appreciated for well-known reasons.

What we first mean as "a better distribution of APT demand among airports" is a re-allocation, thanks better ground access by HSR, of APT demand from centralised, saturated major airports towards medium-sized, under-utilised airports.

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40 Time to connect Rome to Florence (& vice-versa) increases by about 50%; the rail cost decreases by 15%.

41 "Direttissima" feeding the regional airports (Florence) as the programme is a simulation tool and "results" of hypothetical connections may be shown. This is in phase with the case study aim, which is to assess passenger traffic volume shifts towards the one or the other mode of transport, given that data are related to existing conditions.

The opportunity of including rail links to airports has of course been taken (case study part involving hypothesis 12).

42 40 minutes in the applied case of flights Rome-Paris, assuming that travel costs on both alternatives (taking the plane) are the same

As hypothesis 12 involves a situation after the opening of rail station at airports (see Annex 20), where more APT demand has been conditioned to the existence of a hub system prior to the fact of having a HSR station at the airport, there is no difference between the case studies "before" and "after" the Satolas rail station opening. The conclusion within hypothesis 12 (with airport rail stations) is (considering this case study) the same within hypothesis 4.

So, in conclusion ***for the case study Lyon-Paris "before" the existence of HSR stations at airports, there was*** no re-allocation of APT demand towards the Satolas airport and consequently, ***according to the hypothesis 4 meaning no "better distribution of APT demand among airports".***

- **Swedish case study "X 2000"** (new distribution of APT demand in favour of the airports of Malmo (& Copenhagen) & Gothenburg)
  (a European case, the main airport in the country being peripheral. The "situation" in Spain is "contrary" to the "situation" in Sweden, where the main airport is in the "North", that means in the opposite direction to the main air passenger streams (to Europe): see rough drawing in Annex 19)

The question was: Would air passengers continue to connect in Stockholm, when their destination (in Europe) is in the South (see rough drawing in Annex 19)? Experts with SAS and the Swedish State Railway have been asked about aspects related to the behaviour of passengers living between the agglomerations served by X 2000 and to their access to airports by X 2000 or feeder air service. In fact, taking the examples of Jönköping and Växjö, people are already flying to Copenhagen-Kastrup Airport to connect.

However, "things may change" (meaning go much further) when new rail infrastructure is finished. This should be in particular the case, "when the HSR Gothenburg-Malmö is finished"; the airport of Kastrup will then benefit from the rail connection. This (single) expectation view shows concentration lasting at the Kastrup (hub) airport and no new APT demand distribution in favour of the Malmö or Gothenburg airports (medium-sized airports).

At the end, ***fare structures & ticket price strategy*** of air and railway companies (including through-ticketing as combined air/rail tickets or not) will have a main influence on customers' behaviour and choice (switching from air to rail to Kastrup airport for instance).

2.3.5 Conclusions

While dealing with experts' opinion by the outcome of a questionnaire based on the "Delphi"-method, some answers (see abstract in Annex 21) are related to hypothesis 4, as those assessing, "there is an extension of the airport catchment area to be expected, if there are high-speed rail services from an agglomeration without a rail station at its airport" and as "important whether the airport is connected to high-speed rail".

Results for the hypothesis 12 (see Chapter 4.3) are not ***showing for the time being, that is with no (lasting) airport traffic collapse***, a shift towards (medium-sized) under-utilised airports in the distribution of APT demand among airports. We assume of course the same outlook with hypothesis 4 when considering the same background, but without the advantage of any (HSR) rail station at airports.

The questionnaire based on the "Delphi"-method having being answered according to experts' opinion (only), it would be gratifying, if these statements could be strengthened by the case studies under scrutiny:

- **Spanish case study "AVE"** (Madrid- Cordoba- Sevilla)

  As most of the passengers on the Sevilla-Madrid link give connection (transfer) as reason for still choosing APT, the question remains about those connecting air passengers, who choose the AVE, in particular those having Cordoba as travel destination or origin. Moreover, a distribution of the "Cordoba" air passengers between the Madrid and the closer Sevilla airports may be expected. These specific traffic figures/estimates would be much appreciated.

- **Italian case study "Direttissima"** (Florence- Rome)

  Results are provided on passenger traffic modal split (air/car/ rail) between Milan-Florence-Rome, where HSR applies on the Florence-Rome leg; they imply transport backgrounds with "No-Direttissima", that is the status quo ante (by classical trains), and "Direttissima operating". As a computer-based programme on a 1993-data bank is the simulation tool, the effects on (theoretical results but showing the shifts in traffic volumes) HSR, feeding the Rome airport hub from the Florence area on the one simulation, and feeding regional airports in the Florence area while assuming significant delays & waiting times illustrating a (saturated) Rome airport (hub) on another simulation, are quite impressive (see Chapter 4.3).

- **French case study "TGV- Sud-Est before"** (Paris- Lyon)

  There is no difference between the case studies "before" and "after" the Satolas rail station opening. In conclusion for the case study Lyon-Paris "before" the existence of HSR stations at airports, there was no re-allocation of APT demand towards the Satolas airport (see Chapter 4.3) and so, according to the hypothesis 4 meaning no "better distribution of APT demand among airports".

- **Swedish case study "X 2000"** (summing-up the Swedish aspects)

  Feeder air services from regional airports are not going to be ousted by X 2000 rail links, as the examples of air feeder connections using regional flights from Jonköping and Växjö to the Copenhagen-Kastrup major (hub) airport show.

  Moreover, when the HSR Gothenburg-Malmö is finished, the airport of Copenhagen-Kastrup will then benefit from the rail connection. This (single) expectation view shows concentration lasting at the Kastrup (hub) airport and no new APT demand distribution in favour of the Gothenburg or Malmö (medium-sized) airports.

Summing up

Considering the past and the time being (underlined by „TGV-Sud-Est before" & „X2000" case studies), that is with no (lasting) airport traffic collapse, HSR is expected to have either no influence or a contributing effect to concentration at major (hub) airports. Consequently, hypothesis 4 should be refuted as long as the present situation (air traffic concentration at major European (hub) airports) is still affordable.

Simulations carried out along the „Direttissima" show however, that a shift toward less congested airports are taking place, as soon as significant delays, reflecting traffic (near-) collapse, are lasting at major (hub) airports (see Chapter 4.3). These situations may be expected as problems are growing at the major European airports. Consequently hypothesis 4 should be confirmed as soon as the present situation (air traffic concentration at major European (hub) airports) is no longer affordable.

2.4 Which Scenarios of Complementarity between Air and High-Speed Rail Passenger Transport?

One of the new coming ideas about the possible added-value of an HSR network is that some release could be given to air congestion and some limitation brought to air environmental impacts by replacing certain long-distance journeys totally achieved by air, by journeys combining a HSR segment and a rail segment.

The idea could apply just as well to journeys with a direct air connection between origin and destination, and to journeys with an air connection to an intermediate airport.

In order to give to such scenarios the best possible attractiveness, one has probably to restrict for the connection between air and HSR to places where a direct connection between long-distance rail and air at the airport can be seriously considered.

We consequently propose to refer to the list published in the report „Optimising rail/air intermodality in Europe", established by Colin/Buchanan and partners for the Commission, which covers the 12 countries of the union prior to the 1996 extension. This list contains 10 airports already served by long distance rail links, including the TGV services at Roissy-Charles de Gaulle and Lyon-Satolas, and 17 other ones proposed for consideration, most of which on the basis of existing projects or feasibility studies. As a whole, 24 major conurbations spread over 11 countries (Luxembourg missing) are concerned.

It looks however justified considering the geographical scope of HSR infrastructure schemes at the European level, to add to this list the most significant airports of the western European countries not covered in the Colin/Buchanan study, which may lead to add :

- Vienna for Austria and Stockholm for Sweden concerning new member states, Helsinki appearing unlikely to be connected because of its very peripheral position for land transportation,

- Geneva and Zürich for Switzerland and Oslo for Norway concerning non member States.

As a whole, it would then come to a new total of 15 countries, 29 cities and 32 airports, with up to 6 cities per country (situation for Germany -4 for United Kingdom and 3 for France-) and 3 airports per city (situation for London -2 for Paris-)

Among the very numerous possible O-D relations using one of these 32 airports as a nodal point for interchange between HSR and air, three main categories appear of particular interest in the context of this research :

- ***category 1***: intercontinental relations having a European country for initial origin or final destination, with the idea that the European segment of the journey could be provided by a HSR service, releasing the major intercontinental hubs from a part of the short-distance flights acting as feeding services, or giving access to higher frequencies and lower fares than those provided by the local airport;
- ***category 2***: intraeuropean relations having a rather limited potential of demand for APT, assuming that a HSR link from the extremity of the relation offering the lowest attractivity, to an airport already having good air connections to the other extremity of the relation, would improve the efficiency of the transport system as a whole;
- ***category 3***: intraeuropean relations having at least one of the airports involved suffering from a major air traffic congestion, so that an HSR link from the corresponding city to a less congested airport would improve the use of airport capacities as a whole.

These categories, introduced to help in the identification of the different types of benefits that can be derived from HSR/air complementarity, have of course common characteristics, especially in so far as they all tend to decrease the relative share of air in the long-distance transport market. Also, in certain cases, a single relation could belong both to the second and third category, so that one would have to choose whether the most important goal is to increase the profitability of APT, going in the direction of connecting by HSR the smallest extremity, or to release airport congestion, going in the direction of connecting by HSR the biggest city.

Whatsoever, the following list, where (R) means a connection by HSR and (A) a connection by air, could be proposed as an example :

category 1 : Glasgow (R) Heathrow (A) Chicago
Bordeaux (R) Roissy (A) Sydney
Düsseldorf (R) Schiphol (A) New York
Brussels (R) Schiphol (A) Djakarta
Köln (R) Brussels (A) Kinshasa
Sevilla (R) Madrid (A) Lima

category 2 : Antwerp (R) Schiphol (A) Stockholm
Marseille (R) Lyon (A) Copenhagen
Firenze (R) Milan-Linate (A) Hamburg
Sevilla (R) Madrid (A) Geneva
Manchester (R) Stansted (A) Roma
Stuttgart (R) Frankfurt (A) Helsinki

category 3 : Milan-Linate (R) Lyon (A) Lisbon
Heathrow (R) Roissy (A) Barcelona
Düsseldorf (R) Munich (A) Milan

Sometimes, the change of connecting mode will induce a change of connecting place. For example, the Marseille-Lyon rail segment of a Marseille-Copenhagen journey would probably replace a Marseille-Roissy air segment.

Of course, keeping to the same example, the hypothesis of a direct air link between Lyon and Copenhagen could itself be replaced, when considering apart the Lyon-Copenhagen O-D, by the hypothesis of a HSR link to Roissy connecting to a Roissy-Copenhagen flight, which may in that case replace a flight with a stop-over in Brussels.

It is fairly clear that a very large number of combinations is possible, and that the former O-D are more illustrations. In particular, for a given O-D, several possible connecting places could be most often considered seriously, so that a choice may appear necessary, based on a mix of travel time and frequencies, without excluding the relevance to consider eventually more than one single route.

But the diversity of possible scenarios is even reinforced when taking on board other parameters than simply the O-D and connecting points. One of the most critical points is certainly to establish a compromise about the different parameters that may be used for the definition of scenarios between two logics :

- taking into account all the factors that may influence the behaviour of long distance travellers,
- trying to estimate the elasticity of demand to all the parameters introduced, in order to enable a process of disaggregate modelling.

In a first step, one could think of :

- general parameters applicable both to a situation of direct air link and of connection with rail, such as :
  - total time of travel from airport of origin to airport of destination,
  - total price of transport for several characteristics of travellers, period of stay and booking conditions,
  - frequencies by type of period of the day, type of day and type of period of the year (with constraints on the maximum acceptable waiting time in transfer points),
- parameters specific to scenarios including connection, either air/air or air/rail, such as :
  - average waiting time at the connecting point,
  - quality of the transfer between modes,
  - pre-registration of luggage or not.

The main difficulty with general parameters is probably to make realistic assumptions about especially the possible tariff integration between air and rail, which is likely to be determinant of the modal choice considering the practice in APT to offer at nearly no cost the feeder service to long-distance flights.

Concerning specific parameters, the main question is the lack of evidence about travellers behavioural response. The modelling should try to reduce the uncertainties related to parameters' elasticity, taking advantage of any revealed preference data available, and implementing some trade-off analysis about declared preferences applied to the scenarios chosen. It could anyway be wise to include some sensitiveness analysis to changes in the calibration.

Two main results can be expected from such a modelling test of scenarios of air/rail complementarity :

- the establishment of a relationship between the type of O-D and of air/rail connection on the one hand, and the influence on total demand and modal split on the other hand;
- the estimation of the impact of global scenarios of air/rail complementarity for a set of O-D on the variation of traffic for congested and non congested airports.

It will be very instructive from that point of view to examine the results from the research project about to be developed at the initiative of Rhône-Alpes regional council concerning the test of scenarios of complementarity between air and HSR services connecting at Satolas airport.

As a conclusion, a real opportunity exists to produce analysis of scenarios of complementarity between APT and HSR at the scale of the whole of Europe, taking advantage of the experience gained from the modelling of the competition between the same modes.

The classification of models produced as a consequence of the seminar devoted to these questions (see Chapter 2.2 and Annex 15) could help in identifying the most appropriate tools, which should incorporate some ability to deal with complementarity, as well as a disaggregate enough approach considering the level of detail of parameters to be introduced.

3. NEW HIGH-SPEED SYSTEM AND INCREASE IN THE SOCIO-ECONOMIC PROFITABILITY

3.1 The Need for Extended Services on Train

3.1.1 Introduction

In the first thesis of this project - "High speed rail transport is able to compete successfully with APT demand" - the following question is raised: "Extended 'air' service on trains: what level of services is needed?". The context of the question implies that "air service" is better than HSR service. However, one can question whether this is in fact true. Historically we have seen a number of train concepts with excellent service in terms of what attendants provide. The Orient Express can help us visualise the railway's service potential. In general, all services that can be provided in an airplane cabin can also be provided in a train.

The way the question is put suggests that HSR service, during the analysis, is threatened as a variable, while air service is taken as a fixed constant. The questions that arise are: What level of HSR service is required to compete successfully with air, given today's level of air service? What level of HSR service is required to serve as a perfectly satisfactory complement to air traffic, seen from a systems perspective? To make the discussion fruitful the concept "service" has to be given a broad definition. It cannot be limited to include duties of attendants only, but has to include a set of important characteristics like price, travel time, frequency, accessibility, etc.

The subject requires a strong focus on individuals' perspectives. This is obvious when the essence of the analysis is to discuss service levels that satisfy travellers' needs. To some extent, however, transportation companies' perspectives also deserve to be included in the analysis. How can they adjust to meet the travellers' needs? Society's perspective, on the other hand, is intentionally admitted in this chapter.

One cornerstone of an analysis of individuals' perspectives on an issue is to realise and consider that no homogenous group is being dealt with, but a large number of different persons. What is desired by one is not necessarily the desire of another. However, looking for patterns in a world of diversity, there may be reasons to regard certain groups. In this case important insights can be gained by distinguishing between private and business travellers. The first mentioned group is characterised by the fact that they pay for their own tickets, often looking for low cost fares, while the latter are reimbursed by employers, consequently being less price sensitive.

Similarly, there are also reasons to pin-point the fact that a service level experienced by an individual is not a sum of a number of single factors, but a valuation of a package. Nevertheless, when looking for systematised knowledge in the field, there are reasons to also adopt an approach in which individual factors are discussed separately.

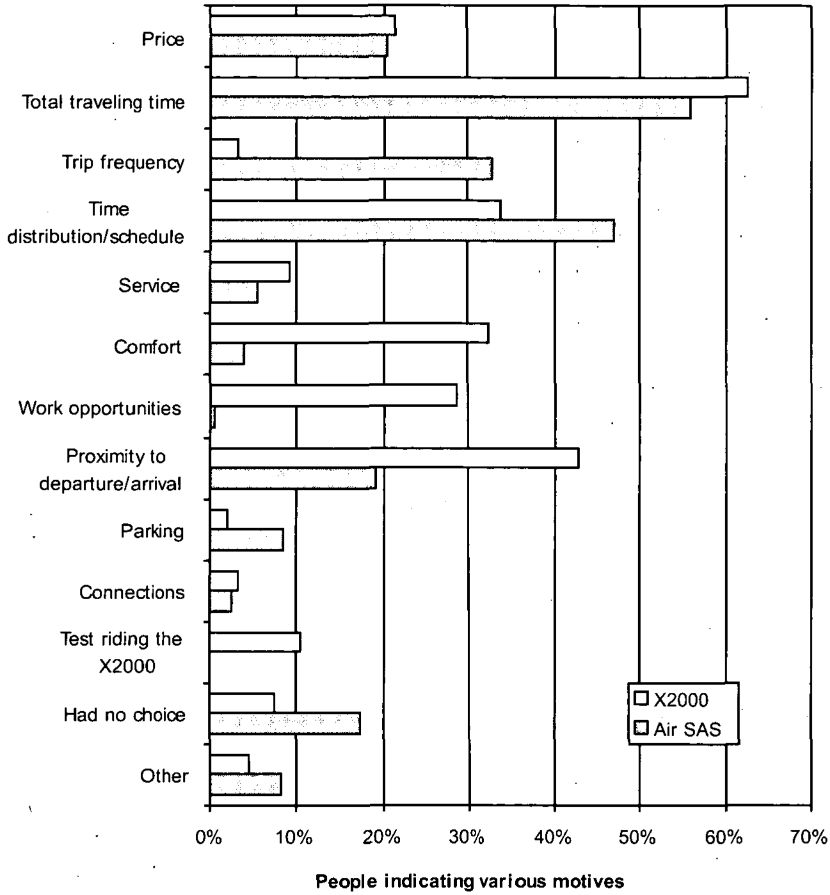


Figure 25: Numbers of people indicating various factors as important for the modal choice for that particular trip 1994

Such an approach has been applied within the national Swedish project connected to the COST 318 study. The study dealt with the introduction of HSR on the line between the major Swedish cities Stockholm and Gothenburg. The project involved a survey based on questionnaires distributed to HSR travellers as well as to travellers on the major airline serving the two cities, SAS. The questionnaires included an attitude question asking for the most important factors for the respondents' modal choice. The travellers were invited to mark three out of about ten alternatives provided. The results from this survey are summarised in Figure 26. It is indicated that HSR has potential advantages concerning such characteristics as comfort, opportunities to work while travelling, the proximity of terminals to origins and destinations, etc. On the other hand, some areas of deficiency are indicated, such as frequency and time schedules for departures/arrivals.

3.1.2 Price and Ticketing Systems

It appears almost self-evident that price is an important factor for the modal choice as well as for the basic decision of whether to carry out a trip or not, especially for private trips.

Fare systems and adjustments to them are perhaps the commonest marketing tool. Basically, traffic companies aim to charge each customer the highest possible fares. Airlines in particular have developed sophisticated systems to prevent business travellers, who have high willingness and ability to pay, from using economy class tickets. Probably railway companies can learn a lot in this respect. Another important characteristic of modern airfare systems are bonus programs. Airlines reward loyalty by bonus systems with certain advantages for frequent flyers. Basically, these schemes offer such customers fringe holiday trips for themselves and/or their families. Similar schemes have not been developed by railway companies.

When discussing rail prices in relation to the cost of flying, it is obvious that the price level needed to compete successfully with air depends on a large number of other conditions. Some of the most important of them will be discussed below. Thus, it is unprofitable to try to conduct a general inquiry into price per se.

It may be justified to comment on the results from the above-mentioned Swedish surveys. At first glance it may appear surprising that price is marked as an important factor for the modal choice by no more than 20 % of the travellers. A number of other considerations seem to be more important. There may, however, be a number of reasons why people do not find price decisive. Most people travelling on full-fare tickets do not pay for their trips; probably their employer would have selected the price alternative to a larger extent. Economy class fares are similar for train and air and hence the price issue cannot be expected to be conclusive. At the time of the survey, inter-regional bus traffic was not a realistic alternative in the comparison.

3.1.3 Travel Time, Frequency and Scheduling

The concept High Speed Rail may indicate that speed in itself is the most important quality. Yet, when analysing HSR travel from a market perspective, ***travel time***, rather than speed, is crucial. It is reasonable to expect that travel time, rather than speed per se, is the significant characteristic that customers experience and appreciate. Still, speed can be of some importance from a marketing perspective. High km/h figures are data that can be communicated to and understood by many potential customers.

In fact, total travel time is one of the most important and decisive factors in the competition between air and rail traffic. When HSR can provide door-to-door-trips at travel times about equal to those of air traffic, experience tells us that the major part of the market will be won. However, not only the relative travel time between the two modes is important. Travel time in absolute terms is also crucial. Travel time short enough to permit business visits during the day increase the market potential considerably.

From the travel company point of view, business trips, with their greater ability to pay, are the decisive market segment for both air and HSR. A large share of all business trips take place during one and the same day. Both business economics and social factors must be considered here. It is expensive for an employer to have an employee stay overnight in another place. If a trip can be completed in one day instead of two, extra costs for overtime, per diem and hotel will be saved. In addition, travelling out and back on the same day makes possible for the traveller to have a more normal private life.

Airlines have caught on to this, and their policy regarding availability of transport has long been that business trips should be able to be completed in one day.

In the HSR context, we often hear about the "3-hour principle". In order to be able to compete seriously in the crucial market sectors represented by the demands of business-class, one-day travellers, what is needed - according to this rule of thumb - is that the overall travel time for a one-way trip must not exceed three hours. Naturally, this does not constitute some absolute limit. Travellers have different preferences. Some can accommodate somewhat longer travel times, others want to get there faster. Empirically, however, it can be agreed that the important threshold lies at about three hours.

This is indicated for example in the market share changes noted following the introduction of the TGV in France and the AVE in Spain. On the Paris - Lyon run, rail travel increased by over 130% while air travel was nearly halved, as can be seen in Table 9.

Distribution of mode of transport Paris - Lyon		
	1981 in %	**1984 in %**
Plane	31	7
Train	40	72
Car & Bus	29	21
	100	100

Table 9: Distribution of mode of transport before and after the introduction of TGV Paris - Lyon.

The experiences from the introduction of high speed rail transport with the AVE in Spain are similar. Today, ca. 1.4 million people travel by AVE between Madrid and Seville, as compared to the previous figure of barely 0,3 million. Studies have also shown that over half of the plane passengers on this run are so-called transfer travellers connecting to another flight in Madrid.

All in all, total travel time stands out as the one decisive factor enabling rail to compete with air. One important dimension of rail's competitiveness is illustrated in Figure 27. For short distances, road transport offers the greatest competition, while flying is important for long distances. The faster rail traffic becomes, the greater will be the distance interval in which rail can compete.

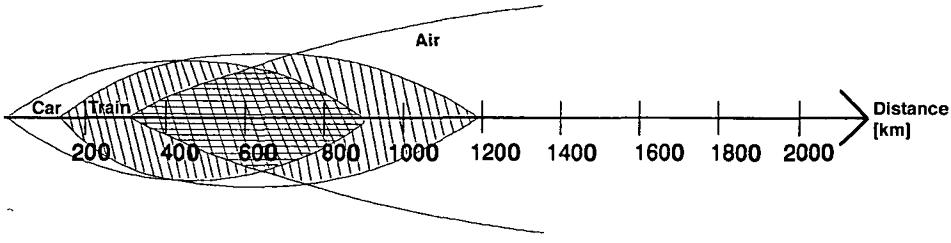


Figure 26: Distance intervals for the principal market of different modes of transport. (The figure does not depict the relative volumes of traffic.)

From the traffic company point of view, the possibility of one-day travel is strategically important for another reason as well. When one-day trips are possible, many business travellers tend to make two trips rather than staying overnight and attending to two errands on the same day. Effects of this kind have been noted in France following the introduction of the TGV. The trip frequencies of many individual travellers have increased greatly, while the time spent at the destination has grown shorter. It is less usual now to schedule two or more meetings for the same trip. It is more common to make one trip for every errand. Not having to stay overnight seems to be appreciated. In addition, trips are planned on increasingly shorter notice because it is easy to book a seat at the last minute. Travel patterns have come to resemble what occurs in a metropolitan area rather than what was once the norm for long-distance trips.

Frequency stands out as the second of the major advantages of flying, after time distribution/scheduling. Operating with smaller planes makes it possible to offer frequent flights even if the passenger base is limited. Rail is fundamentally more large-scale, even though experiments have been made using shorter trains and more frequent departures. Rail's great infrastructure costs are the essential reason for this. One rule of thumb indicates that a well-functioning, "dedicated HSR" requires a passenger base of about 2 million passengers per year. (350 seats * 2 directions * 12 hours of service * 365 days * 0,70 load factor = 2,1 million passengers per year. [21]) Given such demand, HSR can enjoy the prerequisites, with good trip frequency, for attracting sufficiently many passengers to achieve a profitable degree of capacity.

Experiences indicate that systematic timetables with fixed hourly departure times have considerable value for individuals. When there are departures at the same minute, every hour, during the whole day, travellers very soon learn the timetable. A basic uncertainty about and resistance to taking the train are eliminated. Such a timetable, however, tends to involve lack of capacity during peak hours and excess capacity during low traffic periods. This can be countered in a number of ways: extra trains during peak hours, price differentiation, and/or shorter trains during low traffic periods.

In cases where the passenger base is limited, it is doubtful whether investment in special HSR sections of track can be motivated economically. But if HSR traffic can use existing tracks, we see a different picture. It has been proven that HSR can be profitable despite a limited passenger base.

In such combined systems, where HSR shares the track with other train categories, the drawback in terms of low frequency can be met by the use of short trains and good ***time distribution/scheduling***. Departures have to arrive at their destinations early enough to make morning meetings possible. Evening departures back must make it possible to participate in afternoon meetings, but still arrive at the home destination at a reasonable hour.

Two Swedish HSR connections can illustrate this possibility: Stockholm - Karlstad and Stockholm - Jönköping. Both operate one daily departure in each direction (weekdays only). Daily morning departures leave for Stockholm, and the afternoon departures leave from Stockholm late enough to permit participation in afternoon meetings. For about a year there were three departures in each direction on the Stockholm - Karlstad line, but the traffic demand could not bear such a supply. Service had to be reduced by two thirds.

Punctuality is a quality generally allotted considerable importance by passengers. This is particularly true for business travellers. For instance, Swedish State Railway market research suggests that punctuality is one of the most important potential improvements for their rail traffic.

A discussion of HSR punctuality benefits from a distinction between ***dedicated*** HSR systems and ***combined*** systems. Generally, there are very good possibilities to develop a reliable timetable on dedicated HSR systems like AVE, Shinkhansen and TGV. For those systems, punctuality is definitely an advantage as compared to air traffic. On combined systems, like the Swedish X 2000, there are inherent conflicts between HSR and other train categories, resulting in punctuality problems. However, those problems are not necessarily more severe than air traffic's corresponding problems due to weather conditions etc.

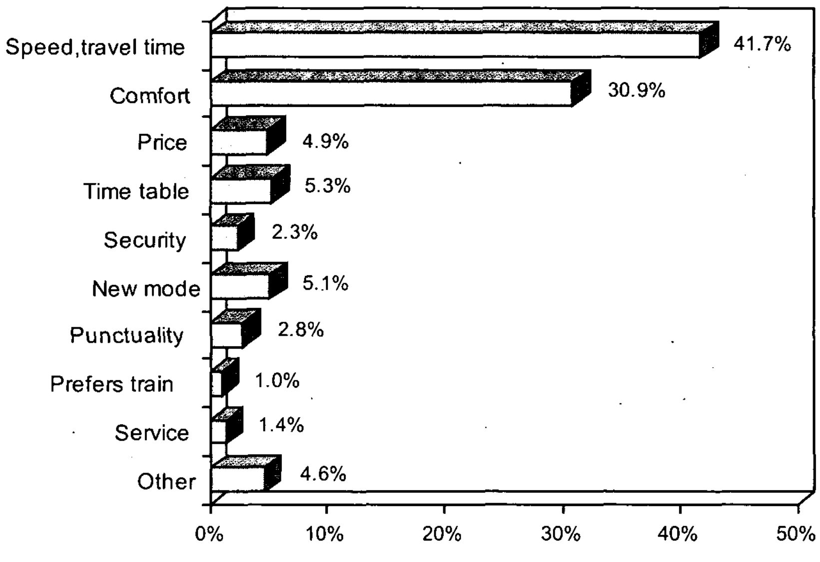
For some HSR systems punctuality is an important area for improvement. But basically, there are no technical reasons stating that punctuality has to be more problematic for trains than for planes. However, it seems as though travellers tend to have a higher tolerance for air traffic delays than they have in general for rail traffic delays.

3.1.4 Comfort, Service, etc.

In terms of comfort, rail travel has manifest advantages over flying because space is more available and cheaper in a train car than in an airplane. On a train, therefore, there is not the same dependence on squeezing in many passengers per surface unit as on a plane. Train passenger do not have to wear seat belts, and normally have better opportunities to move and stretch their legs during a trip. There are no technical obstacles to introducing "in-flight service" on trains, such as serving refreshments along the aisles. Such service is already standard in 1st class on the X 2000 and on the Spanish AVE. One cannot assume, however, that a development in this direction is most appreciated by the passengers. According to reports, the German railway, DB, judges that its customers prefer to get up and walk to the restaurant car rather than remaining on their seats and being served there.

It also appears, from the Swedish attitude survey referred to above, that such factors as comfort and the opportunity to work on board are important reasons for the modal choice by those who travelled on the X 2000 between Stockholm and Gothenburg. As compared with air travellers, more passengers on HSR mention "service" as important in this connection.

The picture presented here is also supported by a corresponding Spanish attitude survey. After "Speed and travel time", which were deemed most important by 42% of the passengers, "Comfort" came in with 31%. All other response alternatives were apportioned palpably less significance (see Figure 28).



Note that only one answer could be given and that no really alternative was available

Figure 27: Most important reasons for Spanish HSR passengers' modal choice. Source: RENFE.

Baggage handling is one factor which appears to be of great significance for modal choice in some cases. The general pattern is that the private car is especially preferable if one has a lot of luggage. According to a Swedish study of the question, problems with luggage are most bothersome for train passengers; 30% of those asked replied that transporting large items is difficult on long train trips, while 25% made the same judgement with reference to travelling by air [22].

In this context, it is important to point out that relatively few travellers have a lot of luggage. As emerged earlier, most business trips take place in one day, or with one or two overnights involved, so not much luggage is required. For people with a moderate amount of luggage, however, there is reason to believe that rail has the advantage over flying. We need only to think on the airlines' problems with the increasing size of passengers' carry-on luggage, despite attempts to counteract this development for reasons of flight safety. Apparently, passengers place a high value on facilitating check-in and not having to spend time at the baggage claim area after arrival. Obviously there is reason for both airlines and rail services to try to facilitate baggage handling. However, there should be no reason for rail to try to copy air in this respect; what it should do is make it easier for passengers to handle their baggage.

Railway stations are generally located in central parts of cities, and airports on the periphery. This provides two important advantages for HSR. First, a majority of the travellers to and from the region are closer to the rail station than to the airport. Second, the railway generally has very good access to the cities' public transport systems. Even if a subway station or a station for regional trains has been established at an airport, the supply of public transport cannot compete with the diversity a central train station can offer. It often includes regional train traffic, a number of subway and/or streetcar lines as well as bus lines. On the other hand, the supply of parking facilities tends to be poor at central railway stations.

The Swedish study referred to indicates the importance of proximity to the terminal in two ways. It shows that travellers with origins or destinations close to a terminal tend to favour that mode. Air travellers are over represented in the surroundings of the airport, while the HSR travellers are over represented in the central parts of the city. In the attitude survey, 40 % of the respondents on X 2000 point out proximity to the terminal as an important factor for the modal choice. About half as many, 20 % of the air travellers, mark this alternative. Thus, proximity seems to be most important for rail travellers, and in fact it is the second most frequently marked of all alternatives.

The importance of proximity to terminals is also indicated by other Swedish studies. Near the international and domestic Arlanda Airport there also is a Swedish domestic airport, Bromma, with very limited resources. Transfer possibilities are virtually non-existent. Bromma is located 10 km from the city, while Arlanda is 43 km away. All destinations that can be reached from Bromma can also be reached from Arlanda. A majority of the Bromma travellers claim that they choose to fly from Bromma because of its more central location.

The location close to the city seems to be a general advantage for HSR competitiveness with air travel. An obvious way to further develop this benefit would be to make stops at additional stations in a city or in its suburbs. Of course, such a development has disadvantages for many travellers in terms of increased travel time. An extra stop can increase the overall travel time by 3 to 5 minutes. Certainly proximity is one advantage to develop, but the way to develop it will clearly depend on specific conditions. No general strategy is to be found.

To summarise, we can draw the conclusion that, generally speaking, there is no reason for the train to try to resemble the plane in such areas as comfort, service, etc. On the other hand, of course, certain elements of airline service concepts can serve as examples while simultaneously developing the advantages already enjoyed in these areas.

3.1.5 Safety and Concern for the Environment

HSR and air traffic are both good alternatives as viewed from a safety perspective. In a technical or statistical context, they are generally about even. Dedicated HSR systems however, seem to be even safer than other railway systems as well as air traffic. Many individuals experience rail as safer than air traffic. It is not unusual that people experience fear of flying, but few are afraid to travel by train. An airplane accident is often more fatal than a rail accident.

Ever since energy and environmental issues appeared on the agenda during the 1970s, rail has benefited from its relative environmental friendliness. Even with regard to energy consumption and air pollution, rail is in something of a class by itself as an environmentally-adapted mode of transport. Should the focus of the debate shift to problems of noise, and perhaps to the area of electromagnetic fields, the situation for HSR might be somewhat compromised. The obvious advantage up-to-now enjoyed from the environmental debate might evaporate. (To illustrate: information provided in a EU study shows that the socio-economic costs for noise associated with passenger transport are estimated to be identical for rail and highway traffic, calculated as ECU per pkm. [EU 1996, p. 46.]) On the other hand, if there is an upward assessment of the carbon dioxide problem, and/or if the emission of pollutants at high altitudes proves to entail particularly great risks, HSR should be able to count on additional environmental support.

During recent years, the environmental issues have been of indisputable importance for most official investments in European rail traffic. Their significance in the market communication with travellers is less clear. Up to now, environmental concerns have not been very important for most business travellers' modal choice. Perhaps they will be of some importance in the future. Companies' travel policies may come to be an integrated part of their environmental policy. As long as HSR traffic is experienced as environmentally friendly, such a development can be expected to be of certain advantage for this mode of transport.

It appears important for the railways to cherish their status as an environmentally friendly form of transport, and for airlines to improve their environmental profile. The natural way of doing this is to tackle the environmental problems associated with one's own activities. This applies both to traditional, familiar problems and to others of which there are only intimations at present.

3.1.6 Conclusions

To make HSR transport able to compete successfully with APT, travel time and frequency appear to be two key elements to focus on during an analysis of desirable improvements of the overall service.

Just as short trip times and frequency emerge as the greatest advantages for airlines, they are also the areas in which improvements can have the greatest marketing significance for HSR. Another major conclusion of the present analysis is that there are no physical conditions preventing trains from fully measuring up to the service and comfort offered by planes. On the contrary. The physical prerequisites for rail to excel in this area are superior - it does not confront the same limitations with regard to space. Empirical studies also indicate that HSR has good possibilities of developing very attractive service concepts.

3.2 Is Air Passenger Transport more flexible than High-Speed-Rail?

3.2.1 Flexibility of Air Transport

Air passenger transport is, by nature, more flexible than road and rail transport. This flexibility comes from the fact that commercial air passenger transport needs as primary infrastructure only aircraft, air traffic control (ATC) and airports.

It is well known that in countries without a good rail or road network or with geographical barriers APT may play a dominant role. This effect is especially important on links with lower demand when this demand is served by regional aircraft not requiring long runways or large air terminals.

However, in the developed countries, and specifically in Europe, APT may suffer from congestion at airports and in airspace. Also there is a strong competition from the private car and bus transport due to the fact that, except in the case of existence of important geographical barriers, road transport may be more effective at short and even medium distances.

Some case examples in which APT is clearly more flexible than other modes may be found in Europe. In particular, if we look to the domestic traffic, we can find European countries in which the superiority of APT is clear. That is the case of Norway or Sweden, where North-South connections would be very slow without the existence of APT (passenger transport from Oslo to small cities as Trondheim, for example, is made with an air bridge of more than 16 flights a day in each direction using turboprop aircraft).

The case of Spain, even without considering the transport to the islands, is also clear. The geography of continental Spain prevented, until the creation of the no-toll motorway network (and the Madrid-Seville HSR), quick passenger transport even between cities separated by less than 400 km. Transport was developed using jets because of the existence of a good network of tourism airports.

This can be also demonstrated on the basis of the recent example of the German unification (Fig. Annex 22 to Annex 24). While the starting of the first new line of high-speed railway traffic (Hanover-Berlin) to the new German states "Länder" is planned not before 1998 and in road traffic there are many highway projects, which are in progress, air traffic has already offered many new lines two years after the German unification the utilisation was accelerated accordingly. For a long time it was not possible, to get to the new German states by road or by rail with acceptable travel times, but already in 1991 air traffic had a nearly complete offer from almost all German international airports (exception Saarbrücken and Münster) to the East German airports of Berlin, Dresden and Leipzig. There were at least one, mostly two or more daily frequencies to these airports. In addition services were arranged from regional airports in West Germany to the East German airports. Connections from West Germany to Erfurt were arranged already in 1991, which were helpful for connecting this region with other German economic centres, because the road and railway lines were still rather insufficient. 4 years later, in 1995, the airport of Erfurt was completely integrated in the German air traffic system. In addition to the opening up of the Southern regions of the former German Democratic Republic, a strong development of the Northern regions of East Germany began, too. So, Rostock was reached by 4 West German airports in 1995. Whereas the network has been extended by only two new airports, the frequencies have in general gone up strongly. Since the road traffic conditions between East and West Germany have improved in the meantime, frequencies on some links especially short distance links, like for example Hamburg-Berlin (Fig. Annex 24) have decreased. Centres like Rostock or Erfurt are now better connected with regional airports, because of the attractiveness of some cities. Air traffic is able to arrange 2 daily flights to many destinations quickly, even if the demand is rather low, for which travellers would need otherwise total travel times of at least 2 working days, if they would use other means of transport. As it can be seen, air traffic has a high flexibility, which allows to react quickly to a new or a changed demand. Most links with a small demand in the beginning and a following increase of demand are built up by an increase of frequencies, mainly with small aircraft, rather than by using bigger aircraft with lower frequencies. Free slots can be used for the building up of new connections.

In this way we should not only see the development of air traffic within Germany, if we look to East Europe, too, (Fig. Annex 25 to Annex 28), we can see the flexibility of the international APT system. While in 1987 and 1989, years before opening up East Europe, only a few destinations, mainly capitals in Russia, Poland, Czechoslovakia, Romania, Bulgaria and Hungary were reached from Germany, we can see a very strong increase of the number of destinations in 1991 and even more so in 1995 (Fig. 29 to 31).

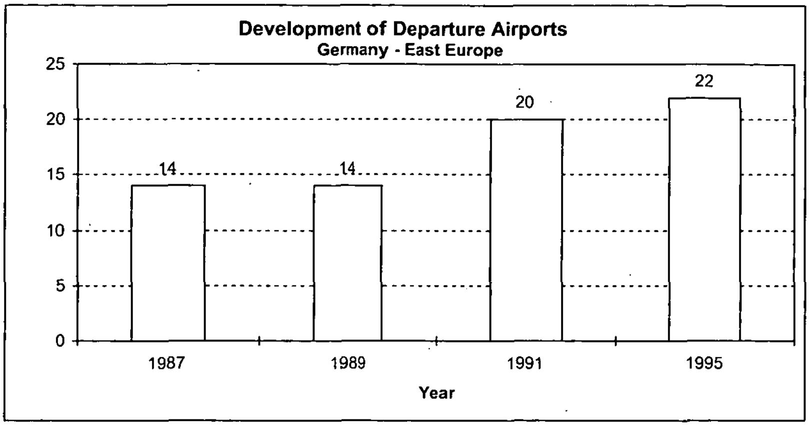


Figure 28: Development of Departure Airports

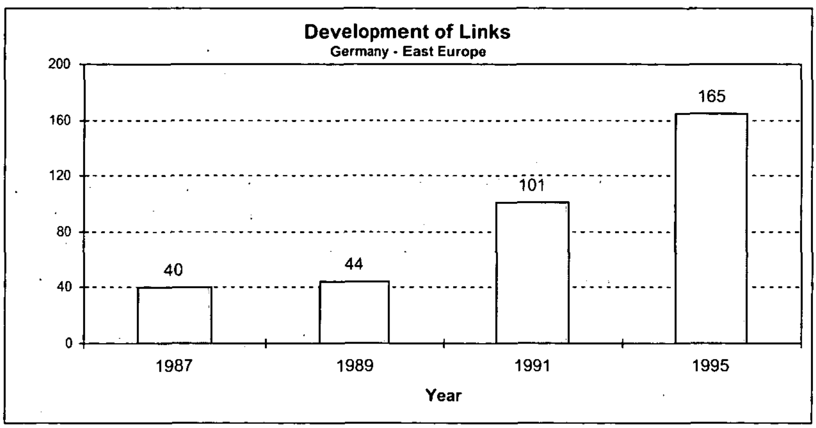


Figure 29: Development of Links

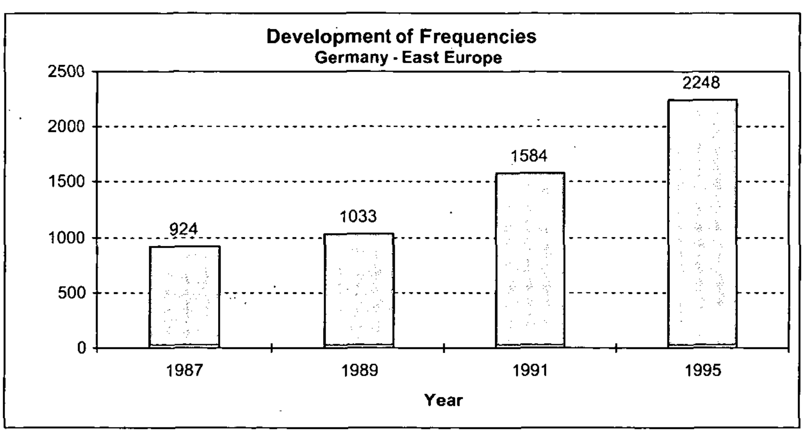


Figure 30: Development of Frequencies

The number of departure airports increased unimportantly and there was only a small decrease of the number of the weekly frequencies on the established links to East Europe in the years 1989 till 1991. This was however accompanied with a strong increase of new city-pairs, the frequencies of which usually start with just 2 flights a weekday for testing the demand. Within a few years air traffic was able to connect large parts of these countries with Germany and Europe, because no other suitable means of transport were available. An opening up with high-speed rail is discussed but realising these plans will require a long period. Beside the spatial flexibility APT offers a high temporal flexibility, i.e. the system is able to react to demand changes with operations that quickly adapt services, that is frequencies and aircraft size.

3.2.2 Conclusions

It has been shown that the APT system is able to react immediately to new transport demand situations, has a high degree of flexibility in adapting the supply to the demand and creating new service and price structures for satisfying new segments of the market.

While building new routes for high-speed rail transport lasts 10 - 20 years (from the beginning till the start of operation) and costs several billions ECU, APT opens the

chance to react on demand changes within a few month's time and with relatively low cost, if the APT infrastructure already exists, as is the case in many European agglomerations. APT can react fast on spatial and temporal changes of demand. An example is the possibility of airlines to change ad hoc the aircraft. In case of the ICE it is not possible to couple an additional unit within a short time. The entry of special trains has to be planned weeks before in contrast to APT where additional aircraft can be chartered normally very fast. The realisation of new services, however, is often limited by the problem of congestion in APT as well as in rail transport.

High-speed rail transport is not able to increase the accessibility of regions within a short period of time and needs a high demand level since on one hand it requires a special infrastructure and on the other hand the routes may only consist of a few stations otherwise the travel time will increase.

APT can operate from distant cities and already a low demand justifies a scheduled use of small aircraft. So APT is able to react fast and without great financial expense to changes in demand. Disadvantages of location of distant economic areas can be reduced by linking them to the international APT, additionally, APT can contribute to the economic development of the region.

3.3 Does Air Transport allow the Saving of important Investment Costs?

3.3.1 Costs of High-Speed Rail Transport

In 1993 the Commission of the EU presented a White „Paper on Growth Competitiveness, Employment". 26 infrastructure transport projects were identified as being significant at European level. For the realisation of these projects 360 billion ECU are needed till year 2010. 9 of these projects, with an investment requirement of 240 billion ECU, serve for the development of high-speed rail. And in these 9 projects there are 14 key links, of critical importance for the network integration and which cost 67 billion ECU. The investments for infrastructure (207 billion ECU) have the highest share of the total costs of 240 billion ECU till 2010 (Tab. 10), while the costs for rolling stock represents just 33 billion ECU.

26 transport infrastructure projects **360 billion ECU**

9 of these projects related to high-speed rail **240 billion ECU**

1) North-South connection (Berlin-Nuremberg-Brenner)
2) PBKAL-connection (Paris-Brussels-Cologne-Amsterdam-London)
3) South connection to Madrid (direction atlantique and direction mediteranee)
4) East connection (Paris-Germany/Luxembourg)
5) Lyon-Turin-Milan-Venice
6) Connection Cork-Dublin-Belfast
7) Connection Denmark-Sweden
8) Nordic triangle
9) Main connection West-England

14 key links **67 billion ECU**

1) Hamburg-Copenhagen
2) Belfast-Dublin-Crewe
3) Amsterdam-Duisburg
4) Connection Strasbourg
5) London-Channel
6) Brussels-Luxembourg
7) Rhine-Rhone
8) Lyon-Turin
9) Barcelona-Perpignan
10a) Lisbon-Porto-Madrid
10b) Victoria-Dax
11) Milan-Basle
12) Brenneraxis
13) Tarvisio-Vienna
14) Connection Greece

Geographically these connections fall into 14 corridors:

1) Corridor Scandinavia-Germany
2) Corridor Ireland -Great Britain-Channel Tunnel
3) Corridor Randstadt-Ruhr-Rhine territory
4) Corridor Paris-East-France-South-Germany (PES)
5) PBKAL (Paris-Brussels-Cologne-London-Amsterdam)
6) Connection between PBKAL and PES
7) Corridor South-Germany and South-France (Rhine-Rhone)
8) Corridor France-Italy
9) Corridor France-Mediterranea-Spain-Portugal
10) Corridor France-Atlantik-Spain-Portugal
11) Corridor France-Germany-Switzerland-Italy
12) Corridor France-Germany-Austria-Italy
13) Corridor Italy-Austria
14) Corridor Central Europe-Greece

40 billion ECU have already been spent until 1993. For the time period of 1994-1999 more than 88 billion ECU are necessary, and for the years 2000 to 2010 there is a need of additional 112 billion. On average, there is a need for investment in the order of 15 billion ECU per year till 1999, which is equivalent to 0.19% of the GDP of the countries concerned, respectively 38 ECU per inhabitant (Tab. 11 and 12).

On the long run the high-speed network will have a length of 29.000 km in the EU countries and the Transalpine countries. 12.500 km of them will be new lines. The costs amount to 207 billion ECU at 1995 prices, whereof 17% has already been spent for projects, which are finished or under construction. For the whole of Europe (without former USSR) the network will have a total length of 35.000 km, with 20.000 km new lines.

Length (km)

New lines	12.500
Upgrade lines	14.000
among which Key links (Tab. 12)	2.500

Costs of infrastructure (billion ECU)

already spent	35
1994-1999	76
2000-2010	96
total	**207**

Costs for vehicle billion ECU)

already spent	5
1994-1999	12
2000-2010	16
total	**33**

Total costs (billion ECU)

already spent	40
1994-1999	88
2000-2010	112
total	**240**

Table10: European infrastructure projects [23]

	Budget already spent			**1994 - 1999**			**2000 - 2010**			**Total**		
	Infra-structure	Vehicles	Total	Infra-structure	Vehicles	Total	Infra-structure	Vehicles	Total	Infra-structure	Vehicles	Total
EU	33	5	38	57	10	67	77	15	92	167	30	197
Switzer-land/ Austria	1	0	1	15	1	16	18	1	19	34	2	36
Sweden/ Norway	1	0	1	4	1	5	1	0	1	6	1	7
total	**35**	**5**	**40**	**76**	**12**	**88**	**96**	**16**	**112**	**207**	**33**	**240**

Table 11: Costs for the high-speed rail network till 2010 in billion ECU [23] **(see also Annex 29)** (1 ECU= 2DM: 1991)

Key link		**Key link**	
Hamburg - Copenhagen	7554	Barcelona - Perpignan	1441
Belfast - Dublin - Holyhead - Crewe	463	Lisbon - Porto - Madrid	5797
Amsterdam - Utrecht - Duisburg	1560	Victoria - Dax	2300
Connection Strasbourg and Saarbrücken	910	Milan - Basel	12907
London Channel	3896	Brenner Achse	12723
Brussels - Luxembourg	554	Tarvis - Vienna	4360
Rhine - Rhone	3479	Connection Greece	2452
Lyon - Turin	6738	Total	67134

Table 12 Costs for the key links (in million ECU 1992)

3.3.2 Costs of Air Transport

The extension and respectively the creation of a transport infrastructure requires in general high investment costs. After presenting the costs for a European high-speed rail network distinguishing between infrastructure costs and rolling stock's costs, which will amount to 240 billion ECU till 2010; in the following section the costs for the European APT system will be calculated. The basic difference between air and rail transport is, that APT is not depending on linear infrastructure but on part concentrated infrastructure. Accordingly the investments are mainly restricted to ground stations, the airports. Concerning the costs there is a difference between the extension of an existing airport and a construction of a totally new airport. The size of an airport generally correlates with the size of aircraft operating at the airport. Major airports are mostly close to big agglomerations, whose air traffic demand allows the operation of bigger aircraft (>80 seats) with high frequencies on definite routes. Remote regions often have smaller airports, from which both connecting flights via a hub as well as non-stop flights to other big centres are offered. Passenger volumes mostly are sufficient only for the use of smaller aircraft.

Air passenger transport in the EU shows a strong dynamic development. The market share of passenger transport (expressed in passenger kilometres) has increased from 2,2% in 1970 to 6% in 1990 [24]. During this time period APT had the highest growth rates of all transport modes. The high rise of air traffic demand has generally lead to a strong pressure on the airport infrastructure in the EC. Transport forecasts by ICAO [25] and IATA [26] are expecting a growth of APT till the year 2010 of an average of 5% per annum. Airport capacity will have to be adjusted to this demand growth. Although airport capacity is not defined exactly, there are three relevant determinators for establishing capacity. These are the ground access to airport, the air access and the ground infrastructure including runways, taxiways and air traffic control [27]. Actually the system of the EU consists of a small number of overcrowded airports, while other airports have a sufficient capacity. According to the airport concept (1991) and the APT concept 2000 (1994) [28] of the ministry of transport of the FRG "air transport has to a great social and economic importance for the FRG. Its further development has be supported [29]". So in the last years great expenditures for airport infrastructure have been done [30]. The biggest investment project was the construction of the airport Munich II, replacing the airport Munich-Riem, with costs of about 8 billion DM. At international level, the costs for the airport with the biggest surface, "Denver International Airport", amounted to 2,8 billion US$.

The big financial difference between extension and new construction of an airport can be demonstrated by the example of Berlin. Berlin itself planned a new airport Sperenberg on a former military area, which should cost, according to a study, "...more than 10 billion DM [31] ". There would be additional costs of 1,3 and 3 billion DM for the connection by road and rail, because until now there are no connections. Sperenberg is located 20 km south of Schönefeld and 45 km away from the centre of Berlin. An extended airport Schönefeld will cost only 1,9 billion DM, with additional 688 million DM for measures of protection against noise and the purchase of land. Caused by the high costs of a new construction, Berlin has decided to realise the Schönefeld project, which will be remarkably less expensive, with a budget of about 671 million DM. The extension of an existing airport may require a great expenditure, too, which shows the example of Amsterdam, where the Airport Authorities prepare a new runway and improve the departure terminal with an investment sum of about 500 million NLG.

Many European airports are planning extensions in the order of some billions ECU. High investments have already been or will be made for the extension of the East-German airports Leipzig and Dresden to meet the demand. The extension of Dresden has already cost 500 million DM and of Leipzig 600 million DM. One further milliard is necessary for a second runway and a rail access. Hanover is planning a terminal C for 280 million DM, Dortmund is looking for an extension till 1998 for 100 million DM, Cologne wants to build a second terminal for 575 million DM, Stuttgart is planning an extension till the year 2005 for 1,5 billion DM, Munich is looking for an airport centre for 200 million DM and Frankfurt will build a gate D for 500 million DM. Beside these extensions, there are a lot of projects at the European level. For example in Spain for 4 billion DM (with Madrid for 1,3 billion DM) or in Denmark for 1 billion DM.

In contrast to the extension of existing major airports the extension of existing smaller airports respectively the conversion of former military airports, for creating new capacities, is essentially less expensive. So for the extension of the regional airport Altenburg, which is similar to the regional airport Mönchengladbach, only 23 million DM have been spent from 1992 to 1996. These costs contain the creation of the technical infrastructure (e.g. ILS) inclusive of terminal buildings, which can manage aircraft of a type Boeing B737 or Airbus A320. These airports are well suited for intra-European point-to-point transport or can act as a connecting airport to the big European hubs.

Similar cost exist between aircraft depending on the size. Whereas a long range aircraft of the type B747-400 (about 400 seats) costs more than 140 million US$, the price for an Airbus A319 with about 130 seats amounts to 35 to 40 million US$, and a smaller aircraft like the ATR42 (about 42 seats) costs only 12 million US$. These aircraft, for short- and medium range, are determined for the national and European region and can be seen therefore, as a potential competitor for high-speed rail transport, if they will be operating on similar routes.

Airport (new building):	Provision	Costs	final extension
Berlin	new building	8 billion DM in future	
Munich II	new building	8,5 billion DM	
Airport (new construction):			
Munich	Airport Centre	220 million DM	
Airport Münster/Osn.		100 million DM	
Bremen	new terminal building	90 million DM	
Frankfurt	new cargo building: Cargo City South + terminal D	25 million DM + 500 million DM	
Hanover	new building terminal C	280 million DM	
Leipzig	new terminal building + 2 runway	130 million DM + 900 million DM	
Cologne	new terminal building + parkarea	500 million DM + 70 million DM	
Schönefeld	highway- and railway connection	145 million DM + 200 million DM	
Stuttgart	upgrade building + new runway	1,5 billion DM	until 2005
Dresden	upgrade building	500 million DM	1990-95
Bremen	new terminal building	90 million DM	
Total investment costs at German airports 1986/87		**500 million DM** **1 billion DM**	**1986** **1987**
International airports:			
Gaza (Palestine)	new building	35 million DM	
Copenhagen	new builiding of terminal 2	1 billion DM	
Madrid	new building of 4,4km runway + new terminal building	480 million DM + 910 million DM	
Amsterdam	upgrade	500 million DM	
Lisbon	upgrade building	98 million DM	until 1998
Spain	upgrade buildings	4 billion DM	1995-1998
Regional airports:	**Provision**	**Costs**	**final extension**
Dortmund	new building of a terminal	100 million DM	
Paderborn	new building of a hangar	2,8 million DM	
Mönchengladbach	Upgrade building and ILS	12 million DM + 3 million DM	
Altenburg	Upgrade building with ILS to a regional airport	10 - 23 million DM	
Air traffic control:			
Rostock-Laage	ILS	2,4 million DM	
Aircraft:			
Airbus A 319	ca. 120 -145 seat	38-40 million US$	
ATR 42	ca 42 seat	ca. 12 million US$	
Intention of purchase			
USAir - Airbus	24 Airbus aircrafts	900 million US$	
China	1320 aircrafts	100 billion US$	1995-2015

Table 13 Investment costs for air transport

3.3.3 Comparison of Costs

For comparing the costs between high-speed rail transport and APT one has to take into consideration, that for both modes the time of planning for a totally new infrastructure are similar. So the first two new projects of high-speed rail lines in Germany had with 25 years the same period of time for planning and construction as the airport Munich II.

In air passenger transport, costs result only punctuate from air and ground access as well as ground infrastructure at the airports. From airports it is possible to offer many services on different routes depending on demand, whereas in case of rail transport it is necessary to build a new line to each new destination. Airport investment costs are in the order of some milliards ECU, whereas the extension of the European high-speed rail network will cost more than 240 billion ECU till 2010, including 207 billion ECU for infrastructure and 33 billion ECU for vehicles. Referring to the European APT aircraft have prime costs of 34 million ECU for an Airbus A319 with 130 seats or of 10,2 million ECU for an ATR42 with 42 seats.

Looking at on the existing APT infrastructure in Europe, one can see that, most airports have been extended according to the growing demand, that a construction of new airports, at least in Germany, does not seem to be realistic. It can be shown that the extension of regional airports will offer an additional supply fast and without high expenses. By the use of bigger aircraft in peak times it is possible to obtain an adaptation to the demand. Thus the high flexibility in the use of aircrafts of different capacity offers the possibility to react on changes in demand fast. If additional aircraft are available it is possible in scheduled air traffic to change aircraft two hours before departure and additional flights may be offered in case of free slots. It is, however, not possible to couple on an additional wagon to the ICE or to add a special train ad hoc; this has to be planned two weeks before the event. Even with the half train concept of the new ICE 2, where two short trains arriving from different directions will be connected to a long train and thus a higher efficiency is achieved, only routes with relatively high demand levels will be served in an economically viable way.

The comparison of the travel prices of the three modes road, rail and air (Tab. 14 and 15) shows that rail transport is cheapest on nearly all connections, keeping in mind that for road transport the total costs for a car (BMW 520i ; Source: ADAC) are quoted. Regarding only the direct operating costs with about 0.15 DM/km (Source: Stiftung Warentest 7/94) the situation is changing, because many passengers already own a car and therefore consider for a trip only the direct operating costs. Hence many passengers make their decision in favour of the car. Calculating with generalised costs when comparing of rail and air passenger transport (i.e. including the cost of travel time) the passenger can save costs on the relation Frankfurt-Munich in relation to the ICE trip (inspite of higher air fares in contrast to rail fares)[32].

from/to	Berlin			Dresden			Dusseldorf			Frankfurt			Hamburg		
	C	T	A	C	T	A	C	T	A	C	T	A	C	T	A
Dresden (time)	2,52	1,36	-	-											
(costs)	159	76	-												
Dusseldorf (time)	6,58	4,50	2,05	7,23	7,56	2,10									
(costs)	444	235	260	464	292	418									
Frankfurt (time)	6,39	5,06	2,05	6,13	5,08	2,00	2,30	2,24	1,50						
(costs)	435	249	381	379	170	380	179	118	284						
Hamburg (time)	3,41	2,59	2,00	6,23	5,22	2,00	4,30	2,54	1,55	5,54	3,20	2,05			
(costs)	212	101	292	363	160	385	322	191	331	411	240	355			
Hanover (time)	3,44	2,22	1,50	5,03	4,31	2,05	3,05	2,21	-	4,01	2,08	1,55	1,47	1,12	-
(costs)	227	121	280	302	126	477	221	121	-	287	183	281	128	85	-
Cologne (time)	6,58	5,13	2,05	7,28	7,37	2,05	0,30	0,20	-	2,07	2,07	1,50	4,52	3,17	2,00
(costs)	458	247	260	469	304	418	36	22	-	151	101	272	349	204	335
Leipzig (time)	2,36	1,48	1,40	1,34	1,26	1,40	5,53	5,23	2,00	4,58	3,34	2,00	4,16	4,29	2,00
(costs)	144	63	115	86	42	199	377	203	391	312	134	367	276	178	363
Munich (time)	7,37	6,45	2,10	5,54	7,04	2,10	7,02	5,46	2,10	4,45	3,12	1,50	8,20	5,08	2,20
(costs)	474	352	260	383	188	381	503	287	260	340	226	288	596	343	465
Nuremberg (time)	5,45	5,33	2,00	4,02	5,14	1,50	5,09	4,56	2,00	2,24	2,08	1,50	6,27	4,08	2,05
(costs)	340	292	357	248	132	423	368	197	345	170	96	278	461	286	406
Stuttgart (time)	7,56	6,18	2,10	6,08	6,41	2,00	4,42	3,41	2,00	2,27	1,25	1,55	7,43	5,34	2,15
(costs)	491	321	260	399	264	385	336	186	318	176	110	263	553	304	426

Source: DB, (costs in DM; travel time in hours, minutes)

Car (C): Cost/Travel time (oneway) lt. ADAC: 79, 5 Pfennige costs for BMW 520i
90 km/h in old states, 70 km/h in new countries

Train (T): oneway from main station to main station; 1. class incl. IC-surcharge

Flight (A): Business Class Lufthansa/ Deutsche BA; travel time (oneway) + 1 hour access /egress

Table 14 Comparison of prices and travel time for the three modes car (C), train (T) and air (A)

from/to	Hanover			Cologne			Leipzig			Munich			Nuremberg		
	C	T	A	C	T	A	C	T	A	C	T	A	C	T	A
Dresden (time)															
(costs)															
Dusseldorf (time)															
(costs)															
Frankfurt (time)															
(costs)															
Hamburg (time)															
(costs)															
Hanover (time)															
(costs)															
Cologne (time)	3;16	2,46	2,45												
(costs)	235	131	325												
Leipzig (time)	3,29	2,55	2,10	6,03	5,46	1,50									
(costs)	216	90	335	389	212	391									
Munich (time)	6,52	4,10	2,10	6,39	5,14	2,05	5,19	5,23	2,00						
(costs)	492	274	397	475	272	387	346	191	378						
Nuremberg (time)	5,00	2,54	2,05	4,45	4,30	2,10	3,27	3,39	1,50	1,52	1,38	-			
(costs)	357	217	333	341	182	330	212	116	398	134	92	-			
Stuttgart (time)	5,57	3,50	2,00	4,19	3,09	2,10	5,41	5,07	2,00	2,27	2,05	2,05	2,21	2,09	-
(costs)	426	254	357	308	171	318	363	214	383	175	108	280	167	81	-

Source: DB (costs in DM; travel time in hours, minutes)

Car (C): Cost/Travel time (oneway) lt. ADAC: 79, 5 Pfennige costs for BMW 520i, 90 km/h in old states, 70 km/h in new countries

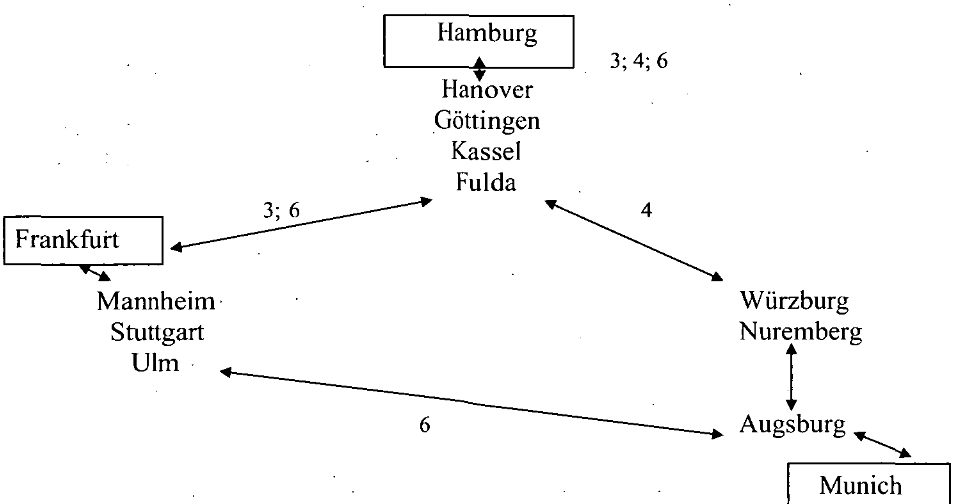
Train (T): oneway from main station to main station; 1. class incl. IC-surcharge

Flight (A): Business Class Lufthansa/ Deutsche BA; travel time (oneway) + 1 hour access/egress

Table 15 Comparison of prices and travel time for the three modes car (C), train (T) and air (A) (Continued)

	frequency/day (return)		Passenger-kilometres	
	ICE	**aircraft**	**ICE**	**aircraft**
Hamburg-Frankfurt	36	30	1.737.50.0	4.782.200
Hamburg-Munich	29	21	8.492.200	4.747.100
Frankfurt-Munich	28	29	10.937.000	3.917.800

Table 16 Comparison between ICE and aircraft



ICE - line 3: Hamburg - Hanover - Fulda - Frankfurt (10+2 wagons)
ICE - line 6: Hamburg - Hanover - Fulda - Frankfurt - Augsburg - Munich (11 wagons)
ICE - line 4: Hamburg - Hanover - Fulda - Würzburg - Nuremberg - Augsburg - Munich (13)

Cost (in DM)	**absolute prices**				**generalised costs (in DM)**					
	normal fare		special fare		leisure		commercial		business	
	ICE	air	ICE	air	ICE	air	ICE	air	ICE	air
Hamburg-Frankfurt	460	710	270	306	561	741	753	874	1392	1232
Hamburg-Munich	650	930	270	405	735	965	1095	1111	2062	1505
Frankfurt-Munich	340	580	270	251	394	611	624	743	1240	1097

Table 17 Comparison of costs between ICE and air

travel time (in h)	access + egress		travel + block time		total travel time		outward + return journey	
	ICE	aircraft	ICE	aircraft	ICE	aircraft	ICE	aircraft
Hamburg-Frankfurt	1.00	1.30	3.40	1.07	4.40	2.37	9.19	5.13
Hamburg-Munich	1.00	1.30	6.04	1.23	7.04	2.53	14.07	5.45
Frankfurt-Munich	1.00	1.30	3.30	1.05	4.30	2.35	4.30	5.45

Source: Prognos (Hrsg.): Vergleich von Umweltauswirkungen von Straße, Schiene und Luft

Table 18 Comparison of travel time between ICE and air

A Europe wide study, sponsored by UIC, which deals with the environmental external costs of transport in 17 European countries, has been made by IWW-Karlsruhe and Infras - Zürich. According to this study, external costs account to 272 billion ECU in 1991. 92% were caused by road transport, while air transport contributes 5,9% and rail transport 1,7% (Tab.19).

absolute external cost of transport		
	in billion ECU	%
17 countries (EU+EFTA)	272,0	100
road	250,1	92,2
rail	4,6	1,7
air	16,0	5,9
inland navigation	0,7	0,3

(Source: Infras, Zürich; IWW-Karlsruhe [33])

Table 19 External cost of transport

3.3.4 Conclusions

In air transport costs arise only locally from air and ground access as well as from ground infrastructure at airports. From these airports it is possible to offer direct services depending on demand to many destinations, whereas in the case of high-speed rail transport it is necessary to construct a new line or improve existing ones to each destination. The construction of the high-speed line Hanover-Berlin will cost ca. 3,25 billion ECU, the investment costs of the new airport Munich II were 4 billion ECU, the extension of a regional airport (like Altenburg), however, for scheduled APT costs only some 10 million of ECU. The construction of the TGV-Est from Paris to Luxembourg, Germany and Switzerland with a length of 450 km will cost

4,4 billion ECU and is planned for the year 2001. A totally new terminal building and a lengthening of the runway at Dortmund airport, which will be finished 1998, costs 55 million ECU.

Based on the existing APT infrastructure in Europe, where airports continuously have to be extended and a construction of new airports in Germany at least does not seem to be realistic, it can be shown that the extension of existing regional airports will offer an additional supply within a short delay and without high expenses. It is not so easy to answer the question if APT allows to save important investment costs. APT is a point to point connection while rail transport has the possibility to collect passengers along the line. So it is possible that depending on demand in the long distance APT is not able to save important investment costs.

3.4 What are the multidimensional Effects of HSR?

The thesis/hypothesis 6 dealing with positive effects of HSR lists a range of very different factors: time savings, transport and operating costs, energy costs, consumption and dependency, air pollution, noise, and airport infrastructure investments (see Annex 31). It is clear that each of these factors deserves a specific consideration.

3.4.1 The Effects on Time Saving

Time savings, referring to the total time spent in transportation, are mostly dependent on two factors : the distance between the zones to be served at the origin and at the destination, and the respective accessibility of the air and HSR terminals at both extremities of the journey.

It is rather commonly considered, on the basis of the first corridor Paris-Lyon and of similar corridors served by the Atlantic HSR, that those relations with a 2 hour HSR travelling time (corresponding at present conditions of commercial speed to a 350-500 km journey according to whether the new infrastructure covers the whole or only a part of the total distance) exhibit the best relative advantage comparing to the air alternative.

Below this. threshold, air is often not present, at least significantly, on the transportation market. Beyond this threshold, and up to a 3 hours HSR travelling time (corresponding, again at current conditions of commercial speed, to a 600 to 800 km journey according to the same alternative as above), the situation between HSR and air is more balanced, and more depending on the precise location of origin and destination.

The advantage of HSR is all the greater than the origin and the destination are :

- close to the city centre, at least if we consider HSR stops using the conventional railway stations, and not specific «gares-bis» in the outer area,
- or remote from the airport location (as a matter of example, it has been observed that a significant part of the air customers not diverted to TGV on the Paris-Lyon corridor, were dwelling in the vicinity of Orly Airport).

Another factor that may influence the relative advantage of HSR in terms of time savings is the reliability of departure and arrival time. The increasing congestion on some European air hubs at present reinforces this advantage, especially for business traffic in peak-hours periods, in so far as departure are often delayed, without necessarily avoiding an increase in the travel time because of congestion at the destination point generating a landing delay.

This question of reliability of time departure introduces another factor which overpasses the sole time spent in transportation, and which relates to the frequencies of services for both modes. It is a disputable matter, according to whether one assumes that travellers are aware or not of the time-tables (which may lead to an asymmetric answer, with a better awareness at the starting point of the journey), and whether they are likely to adapt their activities (which obviously depends of the width of the interval between two services). At an extreme, one should add to the travel time half of the interval between two services, at least for the return trip. In that case, the relative advantage of HSR would be increased by a higher potential of demand (allowing frequencies that only low-capacity planes can justify in economic terms under a certain threshold) and by a limited competition within the air system (or a strong competition within the rail system in the future).

Another important aspect is the possible use of the travel time. Although uneasy to quantify, this factor appears favourable to HSR, in so far as the two/three hours period spent in a comfortable seat without major disturbance is much better adapted to professional activities than a 1 hour period including a large proportion of time neutralised (taking off, meal service, landing) and a rather narrow space available. This could be worth considering at a moment when rail tends to reproduce certain aspects of the air model (meal service included in the first class fare for instance).

3.4.2 The Effects on Operating Costs

The question of transport and operating costs is a rather uneasy one, not so much because of theoretical aspects but due to the strategic value of any related information in the context of the strong competition between HSR and air modes. The main changes in the relative performance of the two modes in the medium-term are probably to be expected not so much from the technology improvements but from the use of human resources and from the choice of operating conditions.

The impact of the number of pilots on the operating costs for air is a well-known example. For rail, the potential for operating costs reduction may lie more on indirect staff volume. Another strategic question is the possibility of an increased use of the tracks capacity within the frame of security rules, either through the access of competitors to the network, or by a mixed use by passenger and freight services of high speed lines, as practised in Germany.

3.4.3 The Effects on Energy Consumption

Energy consumption may appear as one of the most indisputable advantages of HSR. If we refer to a specific study made in Sweden about the Stockholm-Gothenburg relation, it results that the gap between HSR and air is in the proportion of 1 to 7 : the average consumption per passenger-kilometre by X 2000 (Swedish HSR) is about 0,1 Kwh, not significantly different from intercity trains (0,094 to 0,106), whereas the equivalent figure for planes vary from 0,63 (MD 83) to 0,77 (DC9-41), on the basis of a load factor of 0,65. The comparability of figures is ensured by including energy losses from the grid to the train (around 15% for X 2000) and energy required for heating and air conditioning.

The advantage is also quite substantial as compared with car. Under «average» conditions (average 1996 model, petrol fuelled, catalytic converter equipped, with one cold start and a loading factor of 0,33), the energy consumption amounts to 0,57 Kwh per passenger-kilometre.

This strong advantage is even increased if one consider the long-term availability of energy resources, APT being a hundred per cent oil dependant, whereas rail transport is relying on fossil fuels up to only 6%, the major part coming from hydropower (52%) and nuclear power (42%), based on the assumption that the Swedish electricity production mix in 1993 is representative of the electricity generation for train use.

Of course, one should consider that this example is rather unfavourable to air concerning a crowflight-distance of about 415 km, and considering that most of the energy consumption happens at take-off and climb, leading to a better performance in passenger-kilometre as the distance is higher.

However, the conclusions seem to be in line with those of the study undertaken for the Commission in 1993 about Environmental Impact Assessment of the European HSR network. This study estimates that, for the same traffic performance, passenger cars consume 2,3 times and aircrafts 3,0 times more energy than HSR. As compared with conventional rail, the balance between the overconsumption due to high speed and a better loading factor results in the same absolute level.

Indeed, other calculations made for the future on behalf of aircraft industry lead to a rather different appreciation: it is for instance argued by Airbus that in certain charter configurations energy intensities (expressed in megajoules per seat) for such modern aircrafts as A330 are equivalent to HSR, assuming comparable load factors, between 500 and 600 km, and favarouble to aircraft beyond 600 km. (for instance 600 MJ/seat for HSR versus 478 MJ/seat for A330 on Brussels-Geneva relation).

3.4.4 The Effects on Air Pollution

It is clear from what is said above of the relative structure of energy consumption, that the air pollution due to high speed rail is almost neglectible as compared with the one generated by APT.

Concerning the same Stockholm-Gothenburg case, it appears that pollution par passenger-kilometre is at least a hundred time higher for air than for rail transport, whatever the type of pollutant. On the contrary, when comparing with car, it results in significantly more for NO_X, but only slightly more for CO_2 and less for HC, the situation being very diverse according to the type of aircraft for CO.

Another remarkable point evidenced for instance by Swedish calculations on specific emissions from synthetic, average planes of 1995 is that the relative part in emissions of cruise within a total flight of 380 km hardly exceeds 60% for CO_2 (which emissions are approximately proportional to energy consumption) and is significantly lower for HC and CO (about one third).

If we refer to the Commission study mentioned above, the toxicity factor, expressed in CO equivalent, of the HSR emissions is only 1/8 of car emissions and 1/4 of aircraft emissions. Only the SO_2 and PM emission factors are less favourable to HSR than to other means of transport.

Of course, the problem gets more complex when thinking in terms of final impact, considering immissions instead of emissions.

3.4.5 The Effects on Noise Disturbance

Noise impact is one of the more difficult to tackle with, as far as the transition from noise emissions to noise disturbance to people is even more complex than the one from air pollution emissions to immissions. The main point is that the noise disturbance is depending on very local factors, essentially the distance from the source of emission and the protection that may have been implemented, at the initiative either of public authorities (such as anti-noise screens) or of private individuals (such as double-glass windows). Also, it may depend of the existence of previous infrastructures on the same corridor, the logarithmic nature of noise emissions making noise emissions from several modal sources not additive. Eventually, this matter is subject to substantial technology improvements such as the one from «chapter 2» to «chapter 3» aircrafts.

If, in relation with the strong concern of neighbouring populations, studies have been developed around airports on noise impact, it is much more difficult to estimate HSR noise impact, because of the distribution of the phenomenon all along the corridor, and each case being very specific, depending especially on the population density of the areas crossed by the new infrastructure.

The only valuable estimation for our purpose coming from the EC study [47] mentioned above is that the transfer of flights towards the HSR will reduce the noise affected surface around the airports by some 10% on average, on the basis of a sample of 16 airports representative of different sizes.

3.4.6 The Effects on Airport Infrastructure Investments

Eventually, concerning airport infrastructure investments, it looks unlikely that opening a new HSR line serving a city with a congested airport, could do much more than postponing for a limited number of years the need for a capacity extension. The precise impact is of course depending on the relative part of the total airport traffic (or number of plane movements) that could be diverted to high speed rail, as compared with the yearly volume by which the total traffic (or again number of plane movements) may increase in the future. In the purely theoretical case when the hypothesis of building up a new high speed line would be totally dependent on the problem of air congestion, the other obvious comparison to be made would apply to the respective investment costs of airport extension and new high speed line.

3.4.7 Conclusions

As a conclusion, it appears that the most unquestionable positive effects of the introduction of HSR relate to energy consumption and air pollution. The travel time is another item favourable to HSR, although the advantage disappears for most of the customers over the limits of 1 to 2 hours of total travel time.

The noise impact comparison between air and HSR is especially difficult to establish, because of the very different nature of this impact in the air (disturbance to densely populated areas around the airports) and in the rail case (disturbance very much dependent on the density of areas through which the new tracks are built, and on the distance of buildings to it).

Concerning operating costs, the unavailability of information for confidentiality reasons makes it difficult to conclude, but it should also be recognised that significant changes may happen in the future in relation to different operating conditions. Eventually, the saving on airport infrastructure investment is very much depending on the structure of the demand on the considered O-D (see Chapter 3.3).