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Air-rail intermodality



MODELLING OF AIR-RAIL INTERMODALITY FROM PASSENGER PERSPECTIVE AT MAJOR EUROPEAN AIRPORTS

FINAL THESIS

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1 INTRODUCTION

Air transport is a complex industry. When most industries gather together they are faced with a problem of growth creation. In addition, air transport is now facing a number of challenges resulting from this growth and the term “sustainability” is the subject of many debates. An observer from another industry could be excused for thinking that our problem was a luxury problem.

Over the years the air transport industry became used to the luxury of gaining more and more passengers and freight all over the world. The trouble free flow of customers resulted in perceptions amongst certain consumers of a reduction in the quality of service. It is time again to analyse passengers’ needs, in particular after the wake-up call aviation and other transport modes have received in September 2001. The old proverb – time is money – seems to prove its importance. Passengers are requesting fast, efficient and in many cases, environmentally friendly transport connections. Considering the recent situation in aviation, this requirement is very hard to fulfil, especially because of rising delays and congested airspace and airports.

Airport congestion is a mounting problem and already a limiting factor at some airports. Many of the international hubs and major airports are operating at their maximum throughput for longer and longer periods of the day, and some have already reached their operating limits as prescribed by physical as well political and environmental constraints. The use of such airports is heavily regulated. This situation is expected to become more widespread as traffic continues to increase. Furthermore, future traffic distribution patterns are likely to generate congestion at airports that currently do not experience capacity problems.

The solution at the centre of this proposal is to shift short-haul air transport passenger from the aircraft to High-Speed Train. There are numerous advantages to this proposal, principally that it releases runway and ATC

resources, offers immediate relief to congestion, reduces the negative environmental impacts, and finally improves ground access to airports.

The objective of the thesis is to demonstrate the necessity and importance of High-Speed Train inter-modal connections to European airports in particular as a response to passenger needs. Evaluation of major advantages and disadvantages of transport inter-modality is inevitable for closer air-rail co-operation.

The first part of the thesis includes a capacity and demand analysis at major European airports, capturing the current state of congestion. Reading further a new demand model is introduced, describing different travel attributes important from the passenger point of view. The model results in a passenger transport breakdown between air and rail.

The thesis also captures some other demand distribution scenarios, difficulties of air/rail co-operation and finally solutions to questions that arise during the investigation.

2 AIRPORT CAPACITY AND CONGESTION

2.1 *Airport congestion*

2.1.1 *Capacity co-ordination at airports*

Air transport within EU is fully liberalised, and has been since 1st April 1997. That is to say, any airline that is majority-owned by EU nationals may fly any route within the single market, and doing so, may access any EU airport. At the majority of airports in Europe, airlines wishing to operate services need only notify the airport managing body, and their appointed handling agent, of their proposed scheduled.

However, airports do not have an infinite capacity to absorb new traffic. There is a limit to how many landings and take-offs each runway can accommodate. There is a limit to how many aircraft parking stands can be designated. There may be a limit to how many people can physically pass through the terminal buildings. Airports that are approaching one or more of these capacity limits are called scheduled facilities, and they require a certain level of interaction between the airlines and a facilitator appointed by the airport. The process is a voluntary and co-operative one. Another category of airports are those where demand already exceeds capacity, and where voluntary co-operation alone is incapable of solving the problem. These airports need formal procedures to allocate available capacity, and are described as fully co-ordinated. The difficulty is that airlines do not come and go at airports; they come and stay. They invest a great deal of money and a great deal of effort in establishing themselves. For full-service airlines this is more than just developing routes, it is developing networks. [25]

Every airport has its own problems. These are frequently connected with the question when the airport was built and how regional development reacted to its existence, as well as the other way around: In what matter did it contribute to the development of the region?

2.1.2 *Airport problems*

Civil aviation is a strange industry. When most industries gather together in conference their problem is how to create or sustain growth. Oppose to that civil aviation has a problem how to cope the challenge of growth...predictable, sustainable, unrelenting growth. Someone from other industry could be excused for thinking that our problem was a luxury problem.

Airports are on the cutting edge of air travel. Like any player in Air Traffic Management, they have problems – but theirs seems to come in pairs!

- they have to take care of both ground-side and air-side issues
- they have to deal with safety and security
- they are faced with increasing competition that both fuels the desire to give improved service and simultaneously demands that it be done at little or no extra cost
- many airports need to expand so as to continue to provide the kind of service their customers clamour for – but are prevented from doing so by environmental constraints. [8]

2.1.3 *Airport capacity*

Some airports are reaching saturation point and do generate some delay, particularly when other problems compound matters – bad weather, industrial action and the like. However, it should not be forgotten that European airspace is still a good deal more congested than Europe's airports. If efforts to provide airspace capacity are successful, then the capacity problem at airports is likely to worsen and could well become acute.

As traffic continue to increase, the ability of the air transport system to cope with demand is becoming an ever more critical factor. In recent years the public debate has focused on the lack of airspace capacity in Europe. But for air transport, capacity cannot be defined in terms of airspace alone and the term has different meanings for the different players involved. The whole chain of events

that make up the air transport system, including the need to ensure safety and to protect the environment determines capacity.

The capacity of an airport can be limited by the constraints on either air traffic movements or terminal passenger numbers. At different times of the day the limiting constraint may change from one to other aspect of the airport. Congested airports are generally co-ordinated and the function of the co-ordinators is to limit the number of available slots to balance the most restrictive constraint. This kind of co-ordination is only applicable to scheduled airports. Some charter airports are not co-ordinated but might be very congested, the best example being Heraklion in July time. Comparisons between airports are inevitably affected by the lack of standardisation in these practices: one airport may accept an average delay of three minutes while another may accept five minutes for setting the number of available airport slots. Capacity in the air in the immediate vicinity of an airport and the ability of the airport air traffic control system and its runway approach facilities to manage traffic to and from the runways may also have a bearing on general airport capacity. Capacity on the ground must match the capacity in the air and vice versa: only a coherent approach addressing all the elements of capacity will result in an overall improvement in airport capacity. [9]

A capacity analysis is a complex process. The number and placement of runways and taxiways, the types of navigation aid, and the types of air traffic control equipment and facilities determine airport capacity. But other variables such as aircraft performance, the mix of aircraft types, pilot proficiency, weather, and runway closure affect how much of airports capacity can be used at a given time. The capacity in use is often less than the capacity that would be available if there were no such limitations. According to ATM 2000+ Strategy, capacity is a complex mix of access to airports, airspace and services, predictability of schedules, flexibility of operations, flight efficiency, delay and network effects. Clearly the airports of Europe have an obligation to provide airport capacity in sufficient quantity and in good time to meet the needs of the liberalised internal market in air transport and the growing trend towards a more global liberalisation.

2.1.4 Consequences for passengers

If we cannot meet demand there follows a social consequences that is wholly unacceptable. It would mean that some of our citizens would be denied the right to travel by air. The selection could not be done by lottery...it could only be done by price. This would mean increasing the cost of air travel so that only the wealthier citizens could afford it.

Most European airports are, of course, more than adequately equipped to meet the demands of the market. Indeed the problem of 90% of 441 ACI member airports in Europe is to persuade airlines to invest in routes to and from their airports in order that their regions may enjoy the economic and social benefit of air service. [8]

2.1.5 Reasons causing congestion

Many of the problems facing airports are of a political, commercial, regulatory and/or economic nature. These can have a severe impact on the long-term strategies and master plans of individual airports and need to be considered by the airport community and other responsible authorities.

Theoretically, there are sufficient airports and runways in Europe. However, since market forces and other factors such politics and environment dictate the pattern of traffic, the major airports are becoming, or continue to be, bottlenecks, causing frustration and difficulties for both passengers and aircraft operators, and causing environmental problems. These environmental factors are expected to create additional limitations for airport expansion, but, if addressed properly and early, will not become THE limiting factor and will therefore allow sustainability. [13]

Airports should make the best of the potential capacity, as determined by the infrastructure in place, political and environmental restrictions and the economic handling of the traffic demand. The airport therefore needs to be seen as just one part of the whole ATM network in a “gate-to-gate” environment. It is the

point of interaction between the aircraft operators, the airport operator, the passengers, freight shippers, ground handlers and related services, meteorological services as well as ATM. To facilitate swift and effective collaborative decision making, it is imperative that all data that is required to make an airport function smoothly and that will enable full ATM network integration, is made available where it is needed at the moment it is required.

One of the main reasons for congestion in the air industry is that the growth in demand has not been met with an equal growth in the supply of air transport infrastructure. Other major distributors of the congestion at major airports are the airline's way of operation in a deregulated and competitive market. This is primarily the Hub and Spoke means of operation, and the emphasis on high frequency as a competitive element, which results in the use of smaller aircraft. On the other side smaller aircraft accommodation is a capacity generator, a runway accommodating 60 turboprops per hour could accommodate 40 B747's only for instance.

Airport congestion is also caused by political reasons. While few commentators would seriously suggest that spare capacity in one airport could solve the lack of this precious commodity in another airport, there is clearly relationship between the two when states effectively direct traffic and distort the normal functioning of the air transport market. The system of negotiating air service agreements between states, often results in regional airport being deprived of an air service from beyond EU borders, which it may well have fought hard to persuade a third country airline to fly. Governments have been known to refuse traffic rights to a regional airport in order to protect the commercial interest of their state-owned national carrier or indeed due to some political imperative, perhaps unrelated to aviation, in their intricate relations with a third country. [6]

Such policies merely ensure that more traffic is funnelled through already congested hub airports. Whatever is the reason, such interference by governments in the free functioning of the market exacerbates congestion at hub airports.

2.2 Capacity forecast

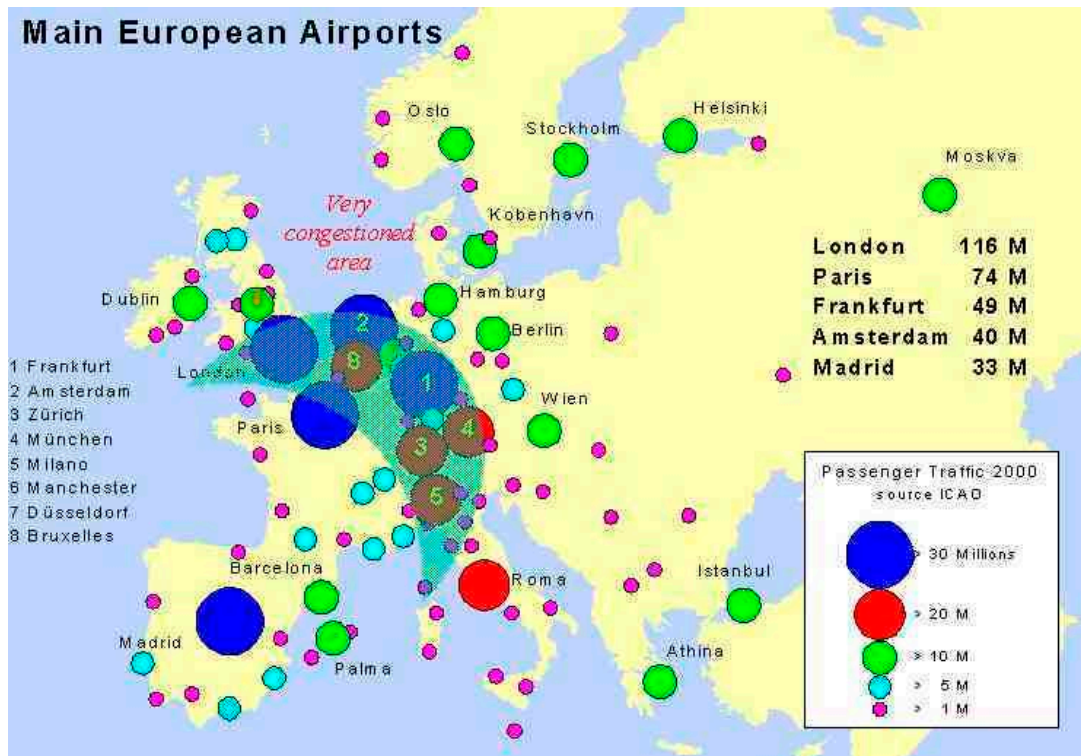
2.2.1 Growing demand

ICAO forecasts a growth in world air travel of 5% per annum until 2005. Based on experience in Europe before 11 September, this appears likely to be a conservative estimate for this part of the world. It is, therefore, not unreasonable to expect that air traffic in Europe may double in the 1997/2015 timeframe as is reflected in the “ATM Strategy for 2000+”.

Airbus and Boeing come to similar conclusion, on the basis of current policies they predict average yearly growth rate in Europe of 5% over the next 20 years or so. This means that by 2020 demand will be two and a half times its current level.

The 1996 APATSI Report suggested that 38 European airports, including several major hubs, may run out of capacity by 2010. The IATA chairman has announced 3 years ago that of the top 39 airports, 25 will have runway capacity shortage, and 26 will have terminal capacity shortage by 2005. Bottlenecks also occur at many airports with respect to apron capacity and landside access. Congestion at airports is a feature of the European industry that is not common elsewhere. European airports have much less capacity than in the US. Of the top 25 international intra-EU routes in 1991, 19 involved a congested airport at one or both ends. [8]

Demand in Europe is heavily spatially concentrated in the “hot banana”, an axis from Manchester in the north through Benelux, Germany and France to Barcelona and Madrid in the south.



2.1 Source: International Union of Railways (UIC) - “Hot banana area”

2.2.2 Importance of Hub Airports

While there have been some capacity enhancement, the policy of the European Union is to “limit the construction of new airports” and it is estimated that by 2005, 25 out of 29 busiest airports will have runway capacity shortages and 26 out of 29 terminal capacity shortages. ICAO has concluded that only Munich, Copenhagen, Milan Malpensa and Oslo of the top 20 airports have sufficient capacity ‘for the foreseeable future’. This information has to be updated by two more airports, Stockholm-Arlanda and Helsinki-Vantaa.

88% of air traffic involves airports larger than 5-million passengers, 40% of total traffic moves between those large airports alone.

Airlines contend that hub bypassing is not the solution. But the vast majority of ACI-Europe members are hungrily seeking to persuade airlines to fly to their airports because they have space capacity.

Most of the existing airports require new runways and/or additional terminal capacity. In Europe between 1997 and 2005 new runways have been or will be built at 17 airports (Vienna International, Sofia, Prague-Ruzyne, Helsinki-Vantaa, Lyon-Satolas, Montpellier Mediteranee, Paris-CDG, Flughafen Leipzig-Halle, Amsterdam-Schiphol, Lanzarote-Arrecife, Tenerife-Reina Sofia, Barcelona, Stockholm-Arlanda, Manchester, Flughafen Frankfurt and two more) and new terminals have been or will be built at 29 airports. The economic and social role of hub airports is finally recognised, by acknowledging the fact that 75% European traffic goes through hub airports. [8]

2.2.3 *Factors influencing growth*

It is well known that growth in air travel is governed by two factors: economic prosperity (for each 1% GDP growth, we can expect maybe 2% air travel growth and more affordable airfares. [20] People want to travel – it is part of their “quality of life” – and more people become more able to travel, so the industry grows. Grows, however, has a downside and can not grow infinitely, there exist a ceiling that is delimited by unaccommodated demand. In an industry which brings together so many diverse elements, stressed and tension arise when different parts grow at different speed. And of course safety must have the highest priority in aviation, safety must not be compromised.

Of all the different modes, air transport has shown by far the largest increase over the last 20 years. Expressed in passenger/kilometres, air traffic has increased by 7.4% a year on average since 1980, while the traffic handled by the airports increased five-fold since 1970. Every day, more than 25 000 aircraft fly the skies above Europe, and judging by growth trends this figure can be expected to double every 10-14 years. [20] Though the skies are vast, this traffic density poses some real problems. The increase number of delays is a clear sign of saturation. In 2000 one flight of six was late, with an average delay of 22 minutes (*data source: CODA*).

The European air traffic control is divided up into 26 subsystems consisting of 58 en route control centres. This is almost three times as many as for a comparable area in the USA (22 in the USA). Europe is handicapped by air traffic control still being insufficiently integrated.

In response to the growth in traffic, it is time to rethink how airports operate in order to make optimum use of existing capacity. However, this will not be enough and Europe will not be able to cope without new airport infrastructure. The current structure of air transport system prompts airlines to concentrate their activities on major airports, which they turn into hubs for their intra-community and international activities. Congestion then centres around the big hub airports, with all the consequent pollution and air traffic management problems. There is already a specific action plan on congestion of the sky, but congestion of the ground is not yet receiving the necessary attention or commitment. Yet almost half of Europe's 50 largest airports have already reached or are close to reaching saturation point in terms of ground capacity. Current schedules at busy airports may have up to 20 aircraft departing at the same time, called a "scheduled delay" (although flights might be scheduled for the same time, commercially. However, there are actually within 15-minute window that is the CFMU slots). Such airports are calling for further efforts to develop integrated management and control system to ensure airport efficiency and safety.

Governments, airlines and airports have all developed measures designed to overcome or ameliorate situations of insufficient airport capacity. However, governments are increasingly likely to face additional situations where airline demands to expand operations cannot be met because of a lack of airport capacity. Despite considerable efforts, however, there remain physical and, increasingly, environmental limitations to the development of new or expanded infrastructure as well as significant funding issues that must be fully resolved. Clearly the best solution is to increase airport capacity through new or enlarged airports, runways and terminal buildings. However, this solution is not always feasible. There is hardly a more important subject to tackle at present than airport capacity and the challenges both regulators and regulated face in ensuring that user-friendly (and

therefore economical), environmentally friendly and sufficient capacity is available to deal with the growth of air transport industry in the near and medium future.

2.3 Capacity studies

2.3.1 ECAC study

ECAC Medium Term Objective (EMTO) group has undertaken a study about “Constraint to Growth” in 2001. It provided an analyses of the ability of the air transport to cope with future demand and overcome constraints to growth, and to set orientations in order to make efficient use of planned airport and ATM capacity.

The modelling was executed for four snapshot years, namely 2000, 2005, 2010 and 2020. In essence, the process consisted of translating the unconstrained annual demand into a corresponding number of departures, en-route and arrival “slots” needed during each hour of the day, throughout the year, for each airport and ACC, taking all network effects into account. This demand for airport and ACC “slots” was constantly compared to the hourly airport and ACC capacities scheduled to be available in the year. The simulation kept track of how many days a year the capacity of individual airports and ACC’s was exceeded (seasonal effect), and all “excess demand” was topped off and set aside as “unaccommodated demand” for each airport, ACC and airport-pair traffic flow (all demand which exceeds capacity by more than 5% should be considered as unaccommodated demand).

This study reveals a number of key messages. As expected there is a growing mismatch between supply and demand. Although the major problems become most apparent in 2020, there are already significant problems in 2005 – the period, which takes account of the most reliable data in terms of capacity enhancement plans. In 2010, 15% of annual demand is unaccommodated.

The modelling reveals that airport constraint become critical before 2005, in particular due to environmental concerns. ATM is also a source of interesting constraints, although these constraints are of different nature.

Year	*	Constraint type	**	***
2000	8,730,000	Airports	78,000	1 %
		ATM + Airports	78,000	1 %
2005	11,995,000	Airports	738,000	6 %
		ATM	113,000	1 %
		ATM + Airports	798,000	7 %
2010	15,159,000	Airports	1,941,000	13 %
		ATM	1,047,000	7 %
		ATM + Airports	2,319,000	15 %
2015	19,048,000	Airports	3,969,000	21 %
		ATM	3,399,000	18 %
		ATM + Airports	4,967,000	26 %
2020	23,324,000	Airports	6,599,000	28 %
		ATM	6,703,000	29 %
		ATM + Airports	8,427,000	36 %

*** Total annual unconstrained movements**

**** Total annual unaccommodated movements**

***** Total annual unaccommodated movements as a percentage of total annual unconstrained movements**

In 2000, according to the model, less than one percent of movements are “unaccommodated”. In 2005, unaccommodated movements increase approximately tenfold but, thanks to existing capacity plans, remain limited to around 6 percent of the total number of unconstrained movements. In 2010, almost two million movements would be unaccommodated by airports, which is roughly two and half times the figure for 2005. In the same period, the number of movements that cannot be accommodated due to lack of ATM capacity increases almost tenfold. By 2015, the figure for movements that cannot be accommodated

at airports is around one third higher than in 2010, which corresponds to an overall unaccommodated demand of around 20 % of annual unconstrained movements. In 2020, unaccommodated demand is equivalent to approximately one third of total annual unconstrained movements (28 % due to lack of airport capacity and around the same figure for ATM capacity).

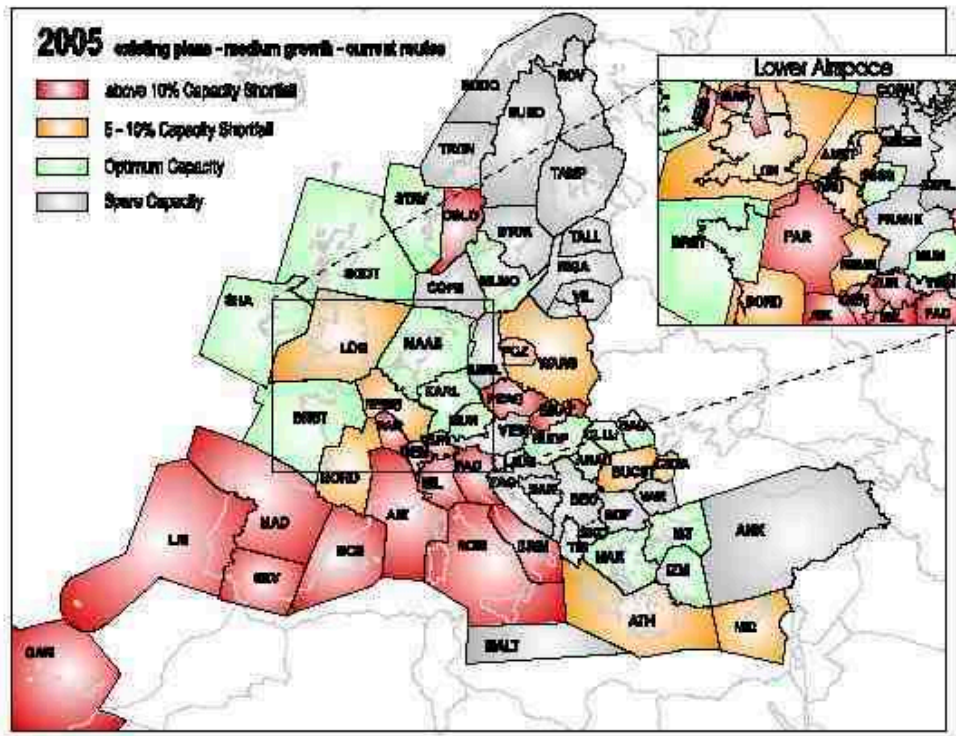
Results show that in 2005, 12 airports and only 1 ACC are expected to have significant unaccommodated demand. By 2010, this increases to 29 airports and 12 ACCs, by 2015 to 46 airports and 33 ACCs, and by 2020 to 62 airports and 44 ACCs. In 2005, Heathrow and Frankfurt are the most constrained airports (providing that Frankfurt's 4th runway is not operational by that time), unable to accommodate approximately 25 % of their unconstrained demand.

By 2010, Heathrow and Frankfurt remain the most constrained airports with 40 and 39 % unaccommodated demand, respectively, but they have been overtaken by Milan ACC, in terms of total number of unaccommodated movements (around 380,000 movements which represent around 27 % of the Milan ACC's unconstrained annual movements). By 2015, Frankfurt and Heathrow remain the most constrained airports, but in terms of total unaccommodated movements, they are behind the London and Milan ACCs, which show unaccommodated annual demand of around 900,000 and 760,000 movements, respectively. By 2020, 16 out of the top 20 bottlenecks, in terms of total number of annual unaccommodated movements, are ACCs. In 2020, 21 % of airports and 16 % of ACCs that are significantly constrained, have unaccommodated demand over 35 % of their unconstrained demand.

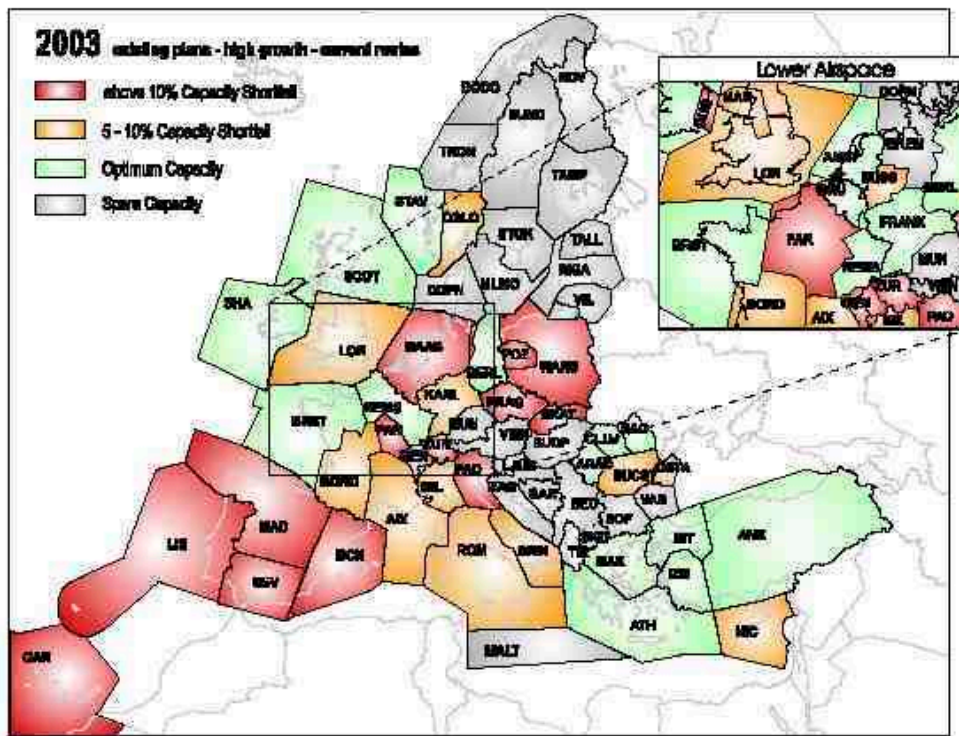
2.3.2 *EUROCONTROL study*

EUROCONTROL Experimental Centre, forecasting the remaining capacity shortfalls and resulting delays in the medium term future (2003-2005) after implementation of national and supra-national capacity plans performed another study. The assumption was that air traffic in Europe grows as forecast by STATFOR (Specialist Panel on Air Traffic Statistics and Forecast), ACC capacities increase as planned by ATS providers and EUROCONTROL, and

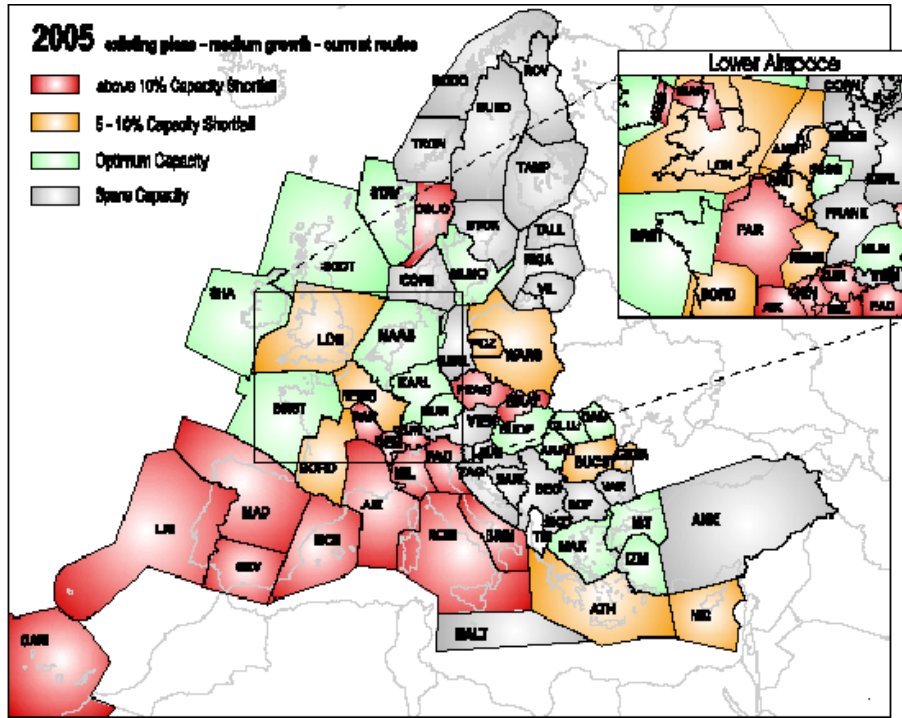
airport capacities increase as declared to EUROCONTROL. The study used an ATFM simulation tool (AMOC/CASA) with implemented copy of the CFMU slot allocation algorithm, using traffic sectorization and capacity data as an input to identify flights subject to ATFM delays and the ACC or airports being the root causes for the delay (bottlenecks). AMOC is used to model the system behaviour of the European capacity network and to quantify the delay development in the future, based on regional capacity and traffic growth estimates. AMOC uses capacities as input and gives delays as an output. It cannot run in the inverse mode, using delays as input and giving capacities as an output. Simulation considered two different traffic scenarios, medium and high traffic growth.



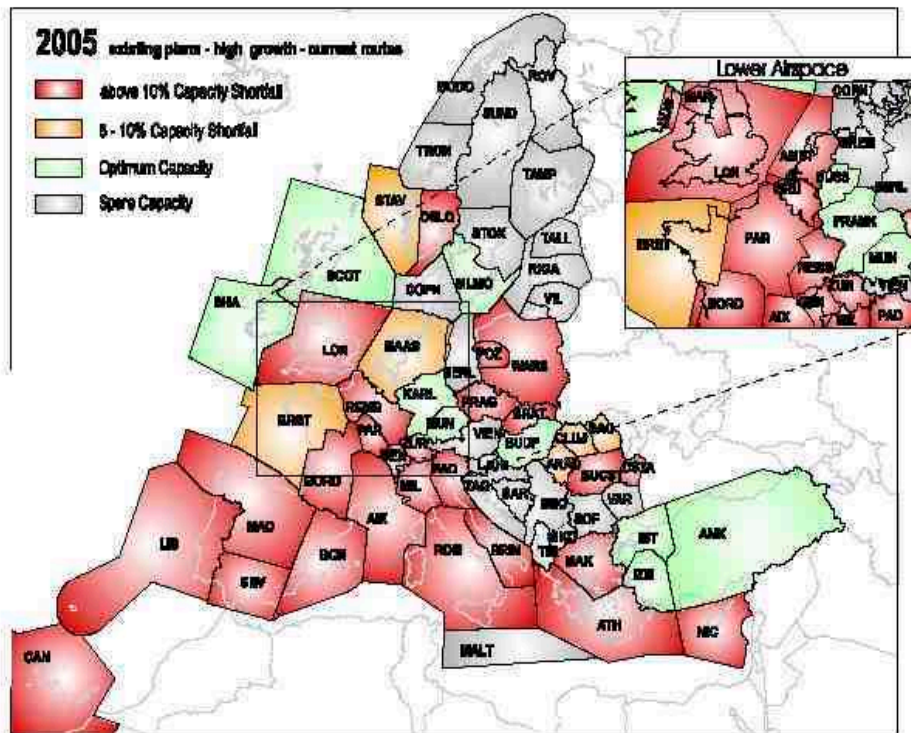
2.2 Capacity shortfall 2003 - medium growth



2.3 Capacity shortfall 2003 - high growth



2.4 Capacity shortfall 2005 - medium growth



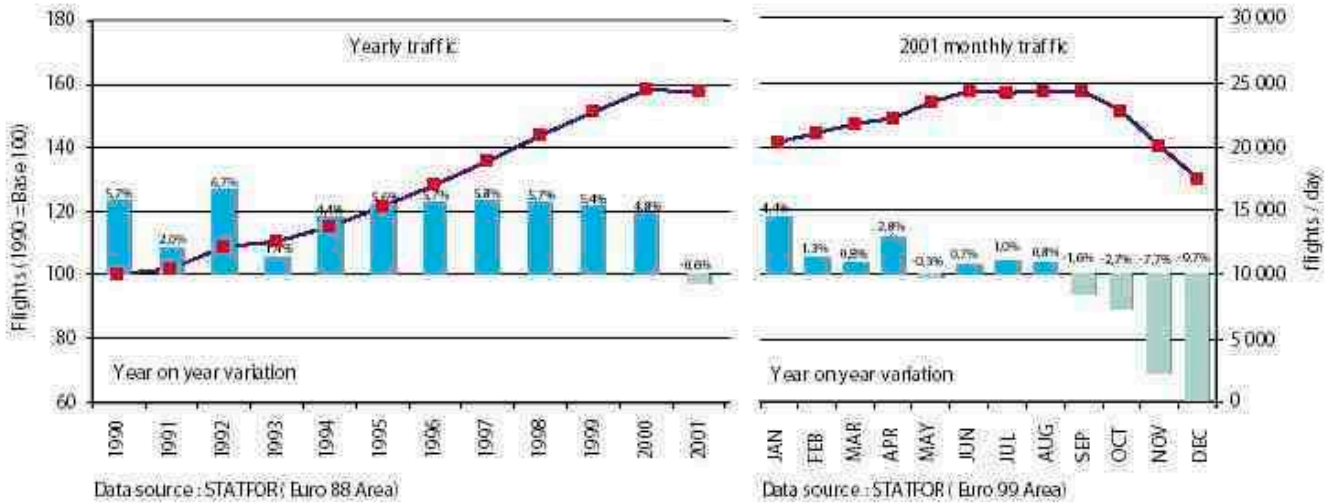
2.5 Capacity shortfall 2005 - high growth

The conclusion was uniform; the European ATM system is not yet prepared for the years 2003 and 2005. The existing capacity enhancement plans are not sufficient to reduce the ATFM delays in the medium term future. On the contrary, delays may increase significantly. The cost for delays in Europe may reach the same order of magnitude as the cost for fuel or the cost of the entire European Air Navigation Services. The majority of the European Air Traffic Control Centre (39 out of 65) risk to have capacity shortfall in at least one of the scenarios tested. The spare capacity of European airports is getting tighter in 2003 and 2005. Consequently, ATFM delays may significantly increase. However, the capacity of overloaded airports will be co-ordinated by scheduled Committee. Consequently, some of the delays observed here may be in future hidden by the means of flight plan co-ordination. Traffic peaks may be pre-smoothed over the day. Unaccommodated demand may move to adjacent airports.

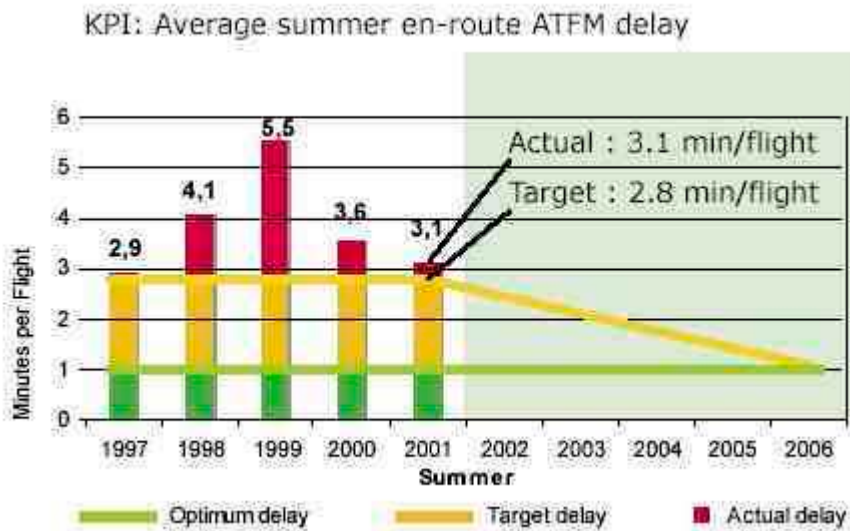
2.3.3 *11 September effect*

Most of the detailed forecast was done before the collapse in international aviation after 11 September. It has affected the air traffic and many airports, although the decline in air traffic was lower than initially feared. As shown in Figure 1.6, air traffic growth will have virtually stopped in 2001 (-0.6% controlled flights) and 2002, after several years of strong increases. After 11 September, lower passenger demand (some -10% in Europe) resulted in severe financial difficulties for many airlines, lower traffic demand, and lower revenues for Air Navigation Service Providers.

Although traffic decreased by 0.6 % during the year 2001, well below planned growth (+5.3%), en-route Air Traffic Flow Management (ATFM) delays (3.1 min) were above the interim target (2.8 min), as shown in Figure 2. Had traffic grown as expected, delays would have been even higher (an estimated 35%). [19]



2.6 Yearly and monthly air traffic increase



2.7 Average summer en-route ATFM delay

3 MILESTONES IN HIGH SPEED RAIL

3.1 *What is high-speed train*

There is no single standard definition of high-speed train, nor even a standard usage of the term: sometimes it is called “high-speed” and sometimes “very high-speed”. HST can be considered from all the standpoints: infrastructure, rolling stock and operating.

From the infrastructure standpoint a line is currently described as a "high speed line" when it is a new one designed to enable trains to operate at speeds above 250 km/h throughout the whole journey, or at least over a significant part of the journey.

From a standpoint of a rolling stock, high-speed stock is normally composed of fixed formation motor coach sets, sometimes coupled together to form multiple units, capable of attaining at least 250 km/h in commercial service. In certain conditions trains of the type mentioned above running at lower speeds (200 km/h), but offering high quality services, such as tilting trains, may also be described as high speed trains.

And finally from the operating standpoint there are 4 types of high-speed system. The most classical “purest” high-speed system constitutes a network of lines used exclusively by high-speed trains which themselves do not operate on any other lines. The example of such system is the Japanese Shinkansen. Another type is a network of high-speed lines, again used exclusively by high-speed trains, but the trains also run on conventional lines, as in the case of French SNCF (TGV train). The Spanish system (AVE) constitutes type 3, system of high-speed lines that are used not only by high-speed trains but also by conventional trains at lower speed. On the other hand, these high-speed trains do not run on the conventional lines. The German (ICE), Swedish (X-2000) and Italian (Eurostar Italia) lines are examples of the last type. In fact all types of train run on the high-speed lines and the high-speed trains run on all types of lines.

As a rule high-speed traffic will be calculated from the infrastructure standpoint; in certain cases, however, limits will be set, e.g. a minimum speed of 160 km/h or a count of the number of long-distance daytime services. High speed is invariably associated with quality service. And it sometimes happens that a service offering a high level of comfort, frequency and accessibility, even when not accompanied by very high speed, is still labelled high speed. [2]

3.1.1 Operating speed

The French TGV-Nord, TGV-Thalys and the Eurostar all operate commercially at speeds about 300km/h. Also the German ICE and the Italian ETR-500 operate at the same speed. The Shinkansen (New trunk line – in Japanese) might be considered as the true HST in the sense that it captures all the ingredients of a HST. These usually include a completely dedicated rail route for the running at high speed (over 200km/h), between two densely populated metropolitan areas (like Tokyo-Osaka 560km); and there is high demand for travel between them (enough to support a high level of service with 290 trains a day on the Tokaido line). In terms of speed there is a technology considered an upgrade to Shinkansen line, the Maglev technology (short for ‘Magnetic Levitation’ – uses electromagnetic forces to cause the vehicle to hover above the track and move forward at theoretically unlimited speeds. In practice the aim is for an operation speed of 500km/h, a speed that has been achieved in tests). Since it has not been in commercial operation to date, it will be not considered in the study. However, since Maglev provides higher speeds, it can better serve as a substitute for aircraft in terms of travel time.

3.1.2 History of high speed train

Immediately after the war, Japan began considering the options for reconstruction, with high-speed rail already very much part of the plans.

1956 saw the first feasibility studies conducted for a new line linking Tokyo to Osaka.

It was decided to design the line for a speed of 250 km/h, setting a new record for that era and representing a remarkable technological leap for a country equipped with a conventional, narrow-gauge (1064 mm) network on which, up until then, trains had been worked at speeds of around 80 km/h. Construction of the new line got under way at the start of April 1959. In October 1964, the Tokyo--Osaka line was opened for revenue service. 60 trains were run daily, with a journey time of 4 hours using the Hikari service and 5 hours with the Kodama service. The venture was an instant success, and, improvements followed in 1965, cutting the journey times between the two cities with the Hikari service to 3 hours 10 min

In 1970 construction work started in Italy on the Rome-Florence Direttissima (trunk line). The project took 20 years to complete, with line sections opened progressively between 1976 and 1992. Journey times on the new line were slashed from three hours to one.

In 1972 the Sanyo Shinkansen line between Osaka and Okayama was inaugurated. By the end of the year, the total number of passengers carried on the Shinkansen network had reached 500 million.

In response to the popularity of high-speed rail in Japan, SNCF had begun investigating options for France in 1966. In 1976, the planned new 410-km line between Paris and Lyons was declared to be of public interest. At the same time, the first section of the Rome-Florence Direttissima was opened in Italy, with further stretched opening at intervals through until 1992.

Inauguration of the South-East TGV line in September by French President François Mitterand took place in 1981, heralding a reduction in journey times between Paris and Lyons from 4 to 2 hours. The line quickly proved to be a success, with annual ridership figures of 15 million, soon rising to 20 million. The opening of TGV South-East services between Paris and Lyon brought an increase of 90% in the number of rail passengers on the route between 1981-90. At the same

time, the air mode witnessed a strong fall in demand from 1980-85, followed by stagnation until 1990.

In 1982 the Tohoku Shinkansen line between Oomiya and Morioka was launched, followed by the Joetsu Shinkansen line between Oomiya and Niigata. The following line in 1985 was between Oomiya and Ueno.

In 1986 Spain joined the high-speed rail club, giving the go-ahead for a new 471-km European-gauge line between Madrid and Seville, opening up the region of Andalusia. Inauguration was scheduled to coincide with the 1992 World Expo in Seville. The travel time has been reduced from 6h30 to 3h32, making total journey time comparable with air. The frequency of flights on the route went from 71 per week to 40 after the HST began operation.

In 1989 the Atlantic TGV line spanning 280 km was launched, with two branches serving Paris-Tours and Paris-Le Mans. High-speed train can now serve all regions to the west of the country. On 18 May, SNCF broke the world speed record for conventional rail, reaching 515.3 km/h.

In 1991 Germany launched the first ICE trains on lines between Hanover and Würzburg (327 km) and Mannheim and Stuttgart (100 km), shaving two hours off journey times and taking the country into the high speed rail era.

1992 was a vintage year for high-speed rail, with several major launches. In Italy, the final section of the Diretissima was opened, while France inaugurated its Rhône-Alps TGV line, by passing Lyons for onward services to Valence. Spain launched its new Madrid-Seville line and the 1st Eurailspeed World Congress on High Speed Rail was held in Brussels.

In 1993 the opening of the 332-km North Europe TGV Line took place, bringing 1-hour journey times between Paris and Lille. The line runs onward into Belgium, laying the cornerstone for a veritable Europe-wide high-speed network

In 1994 Japan celebrated the 30th anniversary of high-speed rail with close to 3 billion passengers carried and no fatalities. At the same time, France and the UK inaugurated the Channel Tunnel, a costly technological feat that overcame heavy odds to provide a three-hour link between Paris and London. The project had been a commercial disaster, which cost overruns that bankrupted the investors

– mainly French. British Railways then still a nationalised undertaking, pressed on with a project and is currently working on a new line section, the Channel Tunnel Rail Link through to London, which will bring the journey time between the two capitals down to 2 hours 30 min by 2007.

1994 also saw SNCF link up its South-East and North TGV line, by passing Paris to the East. In Italy, work began on the 210 km Rome-Naples line.

A major earthquake hit the Kobe region in 1995, wrecking part of the Sanyo Shinkansen line. Three months later, normal service resumed on the route. In November, Finland launched its first ever tilt-body train, worked at 220 km/h on an upgraded line linking Helsinki and Turku.

In 1996 work got under way on the Bologna-Florence line in Italy. The new route would cut across the Apennines and stretch for 79 km, 72 km of it in tunnels, making it the one of the world's most expensive lines. Two launch dates are scheduled: 2003 and 2007.

In Japan, the new line between Akita and Morioka opened in March 1997, served by Komachi trains, followed in October by the launch of the Nagano Shinkansen line and its Asama trains. A new service was launched on the Joetsu Shinkansen line between Tokyo and Takasaki/Yusawa. In December of the same year, magnetic levitation tests began, with a world speed record of 531-km/h set on the Yamanashi test line. In the same year the Spanish authorities gave the go-ahead for construction of a new high-speed line between Madrid and Barcelona, to be opened gradually over the period 2002-2004. The target speed for the line is 350 km/h, the aim being to compete with the airlines by covering the 620 km between the two conurbation in 2 hours 30 min (down from 6 hours 30 min at present). December 1997 saw the inauguration of the international Paris-Brussels line worked by Thalys, a Franco-Belgian consortium, and drawing on TGV technology. The new service puts Brussels at 1 hour 25 min from Paris. The same year Denmark opened the Grand Belt linking Copenhagen to the Jütland peninsula and North Germany.

Since its population density did not warrant major investment in new lines, in 1998 Sweden decided to upgrade existing lines to accommodate speeds of around 200 km/h at a reasonable cost using tilt-body technology. Journey times on the Stockholm-Gothenburg line (455-km) came down to three hours, with four hours for Stockholm-Malmö (610 km). On 14 April, the Maglev beat its own record by notching up a speed of 552 km/h on the Yamanashi test line.

In 2000 The Netherlands started a construction work for a new line to reduce the journey between Amsterdam and Brussels from the current timing of 3 hours to 1 hour 30 min and extend the Thalys network across Europe. Stringent environmental restrictions have hampered work and driven up costs, delaying the launch until 2005.

The same year saw the creation of the Rhealys consortium, linking France, Germany, Luxembourg and Switzerland as of 2006. Paris will then be a mere 3 hours 35 min from Frankfurt via the East TGV, which is an integral component of the new project. 2000 also marked the opening of the 18-km bridge/tunnel link of the Øresund between Copenhagen in Denmark and Malmö in Sweden. Europe's high-speed rail network is expanding fast!

At the same time in the USA, on the New York, Washington, Boston line, the new tilting train service Acela is launched at a commercial speed of 240 km/h (160 mph).

On 10 June 2001, SNCF organised a lavish ceremony to mark the extension of the South-East TGV line towards the Mediterranean. With Paris now a mere 3 hours away from Marseilles, a symbolic step has been taken. A few days prior to inauguration, a test train covered the distance from Dunkirk in the North to Marseilles in the South (i.e. 1000-km) in 3 hours 29 min. [2]

3.1.3 Airports and railways

Seventy airports around the world have some form of air-rail link today and about 200 airports world-wide are considering rail links to connect their

facilities with the greater metropolitan region. In Europe the provision of rail access to airports relies on the fact, that most of the commercially relevant airports are situated (within or) close to agglomerations. Furthermore, there is a large and often dense railway within (underground), around (main line railways) and between agglomerations and that train headways are good. [38]

In 1994, the first airport stations fully integrated into the national HST systems went into operation (Paris-CDG2 and Lyon-Satolas). The next example of this type will be Frankfurt/Main airport, where a second rail station is operational and will be part of the high-speed rail link between Frankfurt and Cologne. HST access primarily aims to extend the airport catchment area for a given acceptable access time.

Airports have undertaken some action to co-ordinate with railway companies. Vienna International Airport operator and Austrian Railways have put together a joint company, to be known as City Air Terminal, which is to put into operation a dedicated rail link between Vienna city centre and the airport's passenger terminals. Another dedicated train has also led to the creation between Stockholm and the nearby Arlanda airport. Arlanda Express has indeed been imposed as a pre-condition to the expansion of the airport serving the Swedish capital. In Switzerland, there is a unique "check-in-and-fly" system through railway stations. You can check in at more than 25 Swiss railway stations for flights on a number of carriers serving the Zurich and Geneva airports. You can also check your baggage to destinations world-wide at more than 100 Swiss railway stations. Moreover, the Fly Rail baggage system lets you check bags from many foreign airports to most Swiss railway stations.

The most recent intermodal development is a feasibility study launched about establishing a direct rail link between the airports at Copenhagen and Malmö, Sweden. The high-speed line between the cities was finished in 2001. The recent opening of a bridge over the Baltic Sea between Denmark and Sweden has indeed created momentum for considering both airports, 30 miles apart, as a single hub whose passengers could be transferred from one airport terminal to the other.

A similar concept is being explored between Geneva and Lyon, 80 miles distant from each other.

Among the “fresh” lines we need to mention is the opening of Frankfurt-Koln line with the “1” campaign signifying that the trip line is being cut down by one hour to 75 minutes, with trains running at 300km/h. German DB AG is doubling its frequency to once an hour. The first month (September 2002) saw average occupancy of 50% in second class, and 60% in first.

Type of link	Conventional	High-speed rail
City-centre to airport	Brussels	Oslo-Gardermoen
	London-Heathrow	
	London-Stansted	
	Newcastle	
	Paris-CDG	
	Paris-Orly	
	Milan-Malpensa	
	Rome-Fiumicino	
	Barcelona	
	Madrid-Barajas	
	Stuttgart	
	Munich	
	Sub-urban and inter-regional rail system at airport	
Geneva		Lyon-Satolas
Zurich		
Birmingham		
London-Gatwick		
Stockholm-Arlanda		
Frankfurt		Frankfurt-Koln
Airport to airport	Zurich to Geneva	Paris CDG2 to Lyon –Satolas

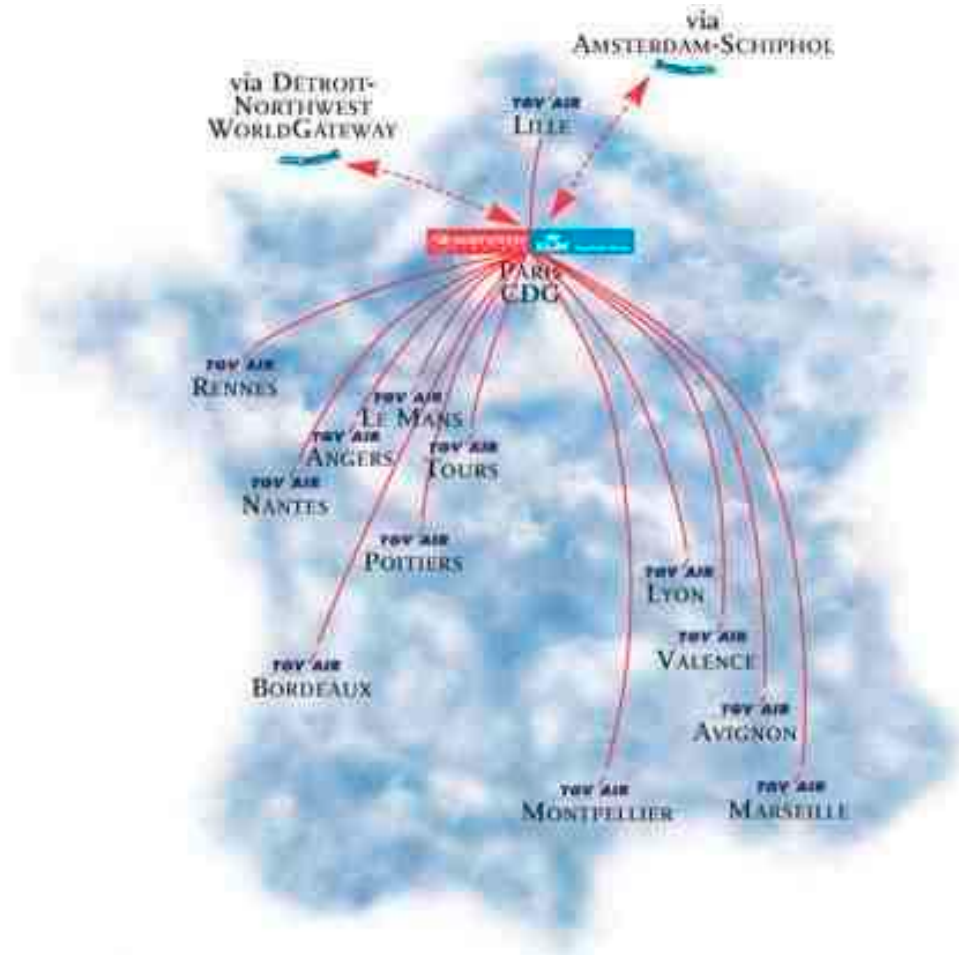
3.1 *Types and examples of airport rail access* [38]

3.1.4 *Airlines and railways*

On 25 March 2001, Thalys International and Air France signed the first bimodal agreement for an international link. Under the terms of the agreement, Air France would replace its flights with chartered Thalys coaches between Brussels-Midi and Roissy-Charles De Gaulle.

Today there are 15 coaches allocated daily to Air France. 90,000 passengers were carried in 2001 under the terms of this agreement and the figure is expected to exceed 150,000 in 2002. With the Thalys' air service, Air France can guarantee its customers fast, comfortable travel, punctuality, no waiting time due to crowded air space and convenient connecting services. Thalys International in partnership with Thalys Nederland, has also developed an agreement with KLM on the Antwerp – Berchem - Schiphol link and works with American Airlines and United Airlines as well.

KLM is a second airline providing a service to connect to 13 French destination, offering a combined KLM/SNCF ticket. Many airlines are now knocking at the door of the French national railway company to join the scheme, which does not yet include baggage handling. At the same time, the French SNCF is exploring the pros and cons of joining one of the global airline alliances.



3.2 KLM & SNCF co-operation

Source: <http://www.thalys.com>

3.1.5 *US projects*

In the US, 10 airport-rail links are in the engineering or construction phases, and will be complete by the decade's end. Ten more projects are in the planning stages, most of which will be underway by 2010. By the end of the decade, 8 of the nation's top 10 airports (and 20 of the nation's top 30 airports) will be served by rail transit agencies. Approximately 70 percent of all US air passengers will depart from these airports. Even in US linking aviation and rail transportation systems together into a more efficient and seamless intermodal system will not only be a convenience, but a necessity.

While ridership number fluctuate, and vary greatly among the rail transit agencies currently serving airports, it can be estimated that between 100.000 and 120.000 people use rail transit to access airports each day. In general, this number comprises 5 to 10 percent of all passengers departing from the airport. Each rail transit system that serves an airport has resolved a different set of design, operational and jurisdictional issues. Cleveland's railway company provided the first the rail/aviation interface. Chicago's Transit Administration (CTA) provided services to two airports (O'Hare and Midway). The CTA has developed strong working relationships with both airport authorities.

In July 1997 a new National Airport air terminal in Washington, D.C. was opened. The new terminal has been moved to a location immediately adjacent to the existing Washington Metro station, ending years of long walks and connecting busses. Serving about 16 million air passengers annually, with about 7 million origination from the ground transportation system, national airport has proven to be the most successful airport rail transit project in the country, attracting approximately 16 percent of airline passengers.

In 1997 Maryland's Transit Administration (MTA) has opened its extension to Baltimore/Washington International Airport. It has been designed to create a seamless transfer between rail and aviation transportation. Maryland MTA, like

other transit agencies currently designing and constructing rail/aviation connections must manage closer interaction with airport facilities, rules, and regulations.

Another project completed in Portland (Oregon) the following year, was the connection of downtown to the airport. An important air-rail project is the Miami Intermodal Centre (MIC) developed to support Miami International Airport (MIA), one of the most congested airports in US. [3]

3.2 *High-speed train prediction*

At the moment in Europe there are 3039 km's of high-speed lines in operation, 2556 km's on works and another 1736 km's in project. If constructions continue as projected there will be up to 10 000 km's of high-speed and upgraded lines in Europe. [2]


Two new lines will link Madrid to Barcelona and Paris to Frankfurt by 2005. Plans for another Pyrenees to connect Montpellier in the south of France to Barcelona by the end of 2005. Besides Japan, whose bullet train started rolling 35 years ago, Australia, China, and Taiwan are considering fast train routes as well.

2002

European High-Speed Network

Réseau Européen à Grande Vitesse

Europäisches Hochgeschwindigkeitsnetz

	new lines lignes nouvelles Neubaustrecken
	upgraded lines lignes aménagées Ausbaustrecken
	IIS Network 2020 Réseau GV 2020 ICI-Netz 2020



High-Speed Division



2020

European High-Speed Network

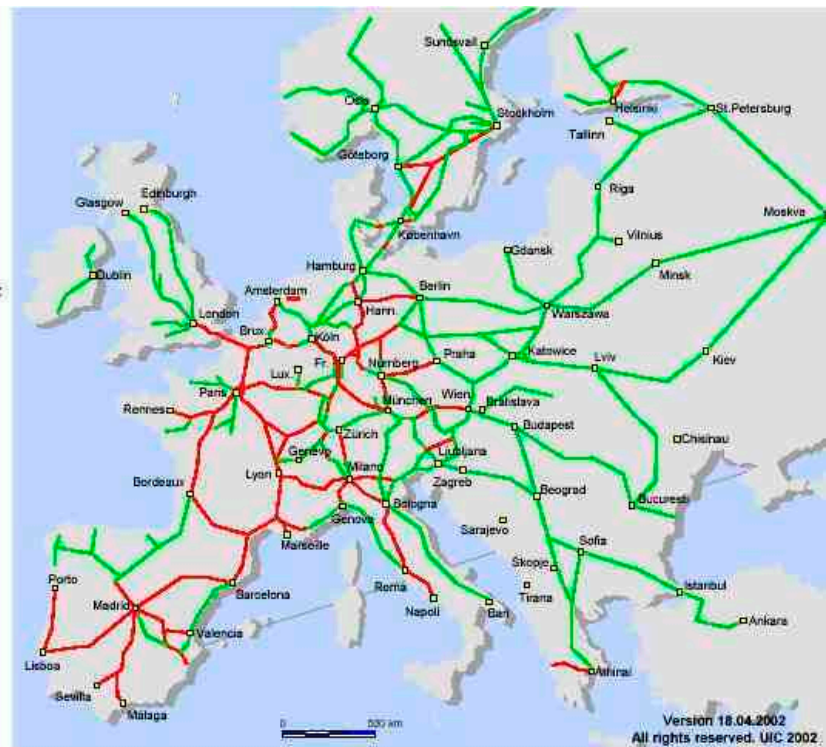
Réseau Européen à Grande Vitesse

Europäisches Hochgeschwindigkeitsnetz

	new lines lignes nouvelles Neubaustrecken
	upgraded lines lignes aménagées Ausbaustrecken



High-Speed Division



3.3 High-speed train network in 2002 and 2020

Source: International Union of Railways

3.4 Studies done on HST substitution

3.3.1 Dutch study

Dutch study about substitution from air to HST concerning Schiphol airport started in 1996, using different model predicting on the basis of previous forecast made by Schiphol airport demand for air transport. The PASO study for the potential demand forecast used mainly income and price elasticity. According to the scenarios with introduction of HST, the substitution from air to HST varied from 8% to 45% of total demand. The most effective substitution factor appeared to be an integration of air and rail services and modified rail-fare structure. The contribution of HST to the goal was the most substantial if tariff trends were differing a great deal from the reference.

The IEE study differed by the use of a more sophisticated substitution model, applied to the demand for London, Paris and Frankfurt, with an extension to 43 other destinations. The parameters were price, journey-time and services for air, rail and car. Parameters used in this model most resemble the demand distribution equation designed for routes Paris-Brussels and Paris-London (see chapter 4), although the model can be applicable on any route. The IEE study confirmed that business travellers are mostly sensible to journey time whereas non-business are much more concerned with fares, also when policies affecting fares or level of services were imposed, there was a higher substitution because of the higher level of air travellers. Although we need to distinguish corporate business travellers, whose company pays and has a policy about the airlines it uses – this type is not price sensitive. Then there is the individual business traveller, possibly in a small company or working for himself/herself – they are price sensitive and will look at low-cost carriers if they provide the right origins and destinations.

Another study was called “The high substitution scenario study” and it used the same methodology as the IEE. The variants of higher substitution consisted in additional HST services, like direct service to London or fast connection to Berlin and diverse increase of air fares (from 24% to 36%) linked or not with increase of rail fares (from constant 1990 to + 4%) and improvement in HST level of service.

Substitution results varied from 2.6 mil of passengers to 15.1 mil. Destinations generating the biggest substitution were those with large number of passengers or within a short distance from Schiphol. [11]

3.3.2 *Spanish study*

The Spanish AVE high-speed rail network, opened in April 1992, has reduced the rail travelling time between Madrid and Seville from 6h30 to 2h32, making total journey time comparable with air. The available data show that the modal split between 1991 and 1994 has changed substantially for public modes, from 16% to 51% for rail, from 40% to 13% for air and from 10% to 5% for coach, the impact on cars being moderate (from 34% to 31%). Concerning the impact on airport congestion, Seville airport has reported a decrease of aircraft movements by nearly 12%, on the other hand, impact on aircraft movements of the more congested Madrid airport reaches less than 2% of the total.

The projected HST between Madrid and Barcelona should reduce the average rail journey time door to door from 8h03 to 3h54, to be compared with 2h38 by air. The line should be operational in 2004. Forecast indicate for this route a shift in the modal split at the year 2022 due to the HST from 10% to 33% for rail and reversibly from 56% to 40% for air, and 34% to 27% for road. Taking into account the creation of traffic, the corresponding reduction in air traffic is by approximately 13%. Barcelona Airport has recently conducted the same study. According to their results around 75% of the passengers will switch from air to HST services.

A preliminary study has been also undertaken about connections by HST between Spain and Portugal. The main route analysed was Lisbon-Madrid, with an hypothesis of 4h09 rail journey time considering shorter than at present, to be compared with an air journey time of 3h15. Forecasts according to the scenario with the choice of the best HST route and a 30% decrease in air fares gives a modal split in the year 2012 of 35% for rail. According to these numbers it is difficult to comprehend the effect of the modal shift on real operation. Meanwhile

the HST line between Lisbon-Madrid has been finished in 2002. Madrid has opened a city centre air/rail check-in terminal with extension to the existing underground railway line in May 2002. Baggage is accepted from 2 to 24 hours before take-off time. Airport construction of the proposed new Lisbon OTA airport has been postponed for at least 6 years. The reason was simple; passengers shifting to new HST link. [11]

3.3.3 *Italian study*

An updated forecast study has been conducted on the high-speed line projects Milan-Naples and Turin-Venice. The traffic was forecasted to be 10.5 billion passenger/km's in 2002 and 17.5 in 2004 considering progressive, among which 77.6% coming from the existing line, 14.3% from road, 1.6% from air and 6.4% being creation of traffic. The transfer from air to rail has been calculated according to two different fares hypothesis, on the basis of price elasticity for 57 airlines likely to compete with the high-speed rail. [11]

3.3.4 *French study*

The methodology of the study has consisted of co-ordinated traffic surveys (same days and same questionnaires) on air, road and rail carrier out in September 1981 (just before starting operation) and September 1984, one year after the opening of the 2h travelling time services between Paris and Lyon. The total traffic increase appears to be very important, around 30% as a whole, and up to more than 40% for origin-destination zones. The modal split has changed considerably, the rail share increasing from 40% to 72% between Paris and Lyon and from 28% to 52% on the overall links between Paris region and south-east. The main counterpart affects the air, its market share collapsing from 31% to 7% as a whole, with huge differences according to the zones: -75% for relations between Paris plus inner belt and Lyon plus department du Rhone, to be compared with only -15% between the outer belt of Paris and Lyon, and even +30% between Paris

region and Province. As a whole, the rail traffic has been multiplied by 1.9 between Paris region and southeast, and by 2.5 between Paris region and Lyon region. Significant impact has occurred on the air traffic between Paris and Lyon, with some release to the congestion of Orly airport.

A similar study has been undertaken about the TGV Atlantique, with surveys in September 1989, just before the opening of the west corridor, and September 1993. Because the “after” survey happened during economic crisis and coincided with the perturbation due to the new SNCF ticketing system The evolution of the modal split appeared unfavourable to the rail. The study anyway confirmed that the most positive impact is to be expected from competition with air for relations with HST journey time between 2 and 3 hours, whereas road remains more attractive under this threshold, as well as aviation over it. [11]

3.3.5 *International studies*

PBKA study (Paris Brussels Koln Amsterdam) project has been studied between 1984 and 1986 by a group with representatives of the four countries served. Results show that the creation of traffic due to HST is mainly coming from relations between big cities (52% instead of 31). In general terms HST speed have a maximum and quite significant effect on traffic between big cities with major airports, and should contribute to a better distribution of demand, although on the specific corridors studied (which excluded at that time relations with London) air traffic is marginal because of too short distances. According to the study, HST has a profitability of its own, which is very dependent at national level on the respective volumes of the flow (with an advantage to France considering the important domestic relation Paris-Lille). The PBKAL became the first of the cross-border high-speed rail projects to be initiated.

European scheme for high-speed rail: CCFE and CCE have ordered a study of the impact of a European scheme of high-speed rail on traffic for year 2010, according to two scenarios of mobility evolution and different steps of

development of the HST network. The modal share of rail in passenger as a whole at year 2010 increases from 12% in the reference situation to 17% in the scenario of maximum extension of the HST network, with a greater impact for business than for leisure traffics. The growth of rail modal share is also more sensible for international traffic than for domestic traffic. About the split between night and day HST, it appears that only 20% of the travellers prefer night trains under 6 hours of travel time whereas 80% choose alike over 8 hours of travel time. Air travellers have the greatest preference for night trains over 6 hours of travel time and the greatest interest for comfort of sleeping. [11]

3.3.6 California study

In 1996 a study entitled the “full cost of inter-city transportation – a comparison of high speed rail, air and highway transportation in California” was conducted on the ‘California corridor’ connecting the Los Angeles Basin and the San Francisco Bay Area. Full cost in the context of the study includes external or social costs, in addition to the internal costs of construction, operation and maintenance. External costs were accidents, congestion, noise and air pollution. The corridor length is 677 km.

	Full cost ²	Internal Cost	Travel Time (cost)	Full Internal Cost ³	External cost
AIR	0.1315	0.11	0.014	0.124	0.0075
HST	0.235	0.19	0.043	0.233	0.002
Highway	0.2302	0.1	0.098	0.198	0.0322

¹ Passenger Kilometres Travelled.

² Full cost = Full internal cost + External cost.

³ Full internal cost = Internal cost + Travel time.

3.4 Comparison of costs in the California corridor for the modes (\$/pkt¹)

Source: Levinson et al. (1996)

Table shows that in the case of the California Corridor, air transport is the cheapest mode and HST and highway transport are both much more expensive, almost double. HST is only slightly more expensive than highway transport. Looking at external costs (accidents, congestion, noise and air pollution), the HST is by far the cheapest mode and highway transport is by far the most expensive.

At the same time, there is a disadvantage to HST in terms of travel time compared to air. This might be in part because it was not city centre to city centre travel time that was taken rather than airport to airport in the case of the air mode. Also, there is still no HST line connecting the cities, so it is not clear whether HST would benefit from the centre to centre time advantage.

In regard to competition between the modes, evidence already exists from different case studies, the best known of which is the Paris-Lyon route. Also described in the Spanish experience on the Madrid-Seville route. [23]

	TGV, Paris-Lyon line		AVE, Madrid-Seville line	
	% in 1981	% in 1984	% in 1991	% 1994
Plane	31	7	40	13
Train	40	72	16	51
Car + Bus	29	21	44	36

3.5 Distribution of mode of transport before and after the introduction of HST

Source: COST-318 1996

4 ADVANTAGES OF HIGH SPEED TRAIN

4.1 Passengers in the spotlight

4.1.1 Passenger needs

Unaccommodated demand in air transport means passengers denied the right to travel. Same as capacity enhancement equals to more passengers in air network. Even if demand is met and services are provided to all the passengers, service provided doesn't necessary mean quality service provided. Passengers deserve more attention. Most of the air traffic actors have no exact knowledge of passengers' expectations and needs. There are some general factors important to passengers and their meeters and greeters:

- an airport should be easily accessible
- it should be simple to find one's way around
- the check-in process should be efficient
- security, passport and customs control should be swift
- flight arrivals and departures should be on time

4.1.2 AENA study

Although these factors are to be taken into consideration, we need to examine passenger needs in more detailed way. Passenger rights are the hottest issue after 11 September. AENA's Barcelona Airport Planning Group has conducted a study based on passenger needs, results of the study are not completely finalised. Findings concluded until now could be related to any other major European airport. The purpose of the study was to understand delay expectations of passengers and their perception of delay. According to 700 interviews undertaken with passengers passing Barcelona Airport, punctuality is the key substitute. Passenger form delay expectations rationally but without full information or incomplete logic.

Surprisingly they tend to accept delay well if they are informed and updated in advance. On a ten-point preference scale, importance placed on delay averages 7.7. According to the survey both departure and arrival delay are important attributes of the trip chain (7.55 for departure, 7.81 for arrival). Arrival delay is quoted to be 20% more important to the passengers than departure delay. A rather impossible to fulfil request is concerning the expected time spent at the destination airport. Passengers expect to be out of the airport in 9 minutes if travelling without luggage and in 21 minutes with luggage. Passengers with luggage are more sensitive to delay than passengers without. An interesting observation conducted from the study is about the arrival time. Most of the passengers have no exact knowledge of arrival time, although 50% of the passengers want to arrive earlier than the scheduled arrival time. Waiting at the destination is preferred above waiting at the hub airport. Final results conclude that passengers' expectations on airport arrival processes performance are higher than assumed by industry managers.

4.1.3 Main benefits of intermodality

Safety, accessibility, speed, efficiency, employment, flexibility, proper land use, and pollution control together form the main benefits of intermodal transportation system offered to passengers. Intermodality calls for co-operation with the view to:

- Satisfying customers' expectations through the selection of best practices.
- Promoting the most cost-effective use of the means of transportation.
- Reducing the congestion, air traffic control delays and environmental impacts.

[33]

The evolving technology and increase future use of the HST is considered to be a comeback for a transport that had "had its days". The reason is speed.

4.1.4 Speed

The current commercial speed of HST makes it possible for the train to compete with air services in journey time terms on some short haul routes. Other than speed, it is the fact that most cities' rail stations are located in the city centre, while most airports are in the cities' outskirts which gives HST the advantage when comparing city centre to city centre travel time. It is important to remember that, almost regardless of any other advantages in shifting traffic from air to rail, it is the travel time feature that would determine the scale of any likely shift. [23]

Of course HST is not a comprehensive solution. HST does not fully replace air services, although it is capable of shifting a substantial amount of traffic from the air mode. According to COST-318 analyses travel time and frequency appear to be two key elements to make HST transport able to compete successfully with air transport. It might be the case that airlines services have the advantage of offering better frills e.g. stewards, meals, movies in their services and this has an effect on modal choice, but the railways have greater possibilities to offer a higher service quality because of larger space on trains compared with aircraft.

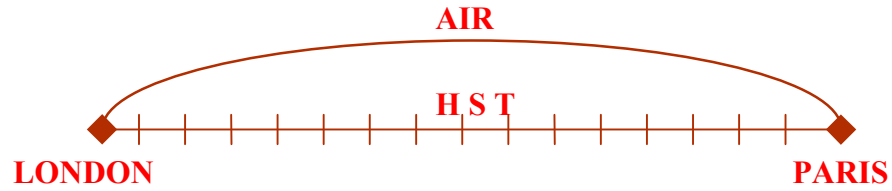
4.2 *Current air-rail co-operation*

4.2.1 Relationship between air and rail services

Three different types of relationship can be identified between the rail and air services. First (A), competition between the modes on the same route. Example of air-rail competition is a route where two different companies are involved, the railway and the airline. Second (B), complementarity between the modes. The rail services complement the air services by offering connection from the city airport to the city centre (by HST, rail or metro services), or by offering connection from the airport to nearby cities. Again two different companies, independent from one another, are involved, the railway and the airline.

The third type of relationship (C) can be described as co-operation. The rail services replace previous air services on short haul routes. In this case either one company, the “Airline”, is involved or two companies, the railway and the airline, that operates under Code-Sharing agreement. The third type of relationship is in the centre of the study. [23]

A: COMPETITION



Companies: Airline, Railway

B: COMPLEMENTARITY



Companies: Airline, Railway

C: CO-OPERATION



Companies: 'Airailine' or Airline-Railway Code-Sharing

4.1 Types of relationship between airline and railway.

4.2.2 *Benefits*

Air and rail modes are complementary, as high-speed trains can be used to replace airline services. Most studies, however, consider the two modes to be in competition. Complementarity is only mentioned in the sense that rail is used to improve access to airports.

Assuming travel time, frequency and level of services are the same on certain routes, for both air and rail services, most passengers would be indifferent to what mode they use. This means that using a train rather than aircraft when offering airline services should have no effect on demand. But, it could have an impact on the supply of airline services. Using HST instead of aircraft would allow airlines to expand operations even at congested airports, as well as gaining other benefits (e.g. operate long distance flights, reduce environmental impact). [23]

4.2.3 *Why High Speed Train*

Shifting traffic to the HST might ease the congestion problems in the air transport industry (which is expected to intensify). This would release ATC and runway resources; it would have a positive environmental impact; it would allow the growth of airlines and airports (in passenger numbers); and it would bring to the rail industry the standard and skills developed in the airline industry, as well as other benefits. But most of all it would allow more passengers to reach their destinations, without facing difficult congestion constraints.

A traffic system is as strong as its weakest part. Tremendous gains in productivity are possible if air and rail networks are developed together. Excellent examples already exist in Europe. With the Heathrow/Paddington Express, BAA has shown that a private funded air/rail project is possible. The importance of intermodality in transport is indeed widely accepted in Europe.

In Europe the provision of rail access to airports relies on the fact, that most of the commercially relevant airports are situated (within or) close to agglomerations. Furthermore there is a large and often dense railway network within (Underground), around (main line railways) and between agglomerations. [38]

HST services may be seen as an alternative and challenge to the regional feeder flights at the increasingly congested main airports as air transport liberalisation and competition lead Europe-wide to a concentration of air transport activities at some airports due to the development of hub-and-spoke systems by many airlines.

Airport HST access takes advantage of the specific advantages of rail transport over the car. These advantages differ for the various factors, such as the railway and airport operators, the air travellers, the airport employees and the general public. These advantages may be summarised as follows: high volumes of transport per time unit, which, associated with high frequencies, provide a large capacity reserve, with little need for (parking) space at airport. Furthermore, timetable based service reduces time margins, which need to be accepted. [38]

Moreover HST transport has an acknowledged lead in terms of safety and in terms of air pollution. And isn't safety one of the main features of transport that passengers are asking for more and more?

4.3 Enlarging the catchment area

4.3.1 Passengers can choose

Where the catchment area of several airports overlap thanks to a HST access, users have the choice to shift to other airports. Considering air passenger transport trends, boosted in particular by European air transport liberalisation, "airport choice opportunities for users will increase (just as present airline choice opportunities)" as airports will be keen to offer new services according to

flexibility and market opportunities (just as airlines are doing it), competing between them: this speaks for airport rail connection whenever feasible!

Travel distances in Europe are shorter. For many18/02/03 significant origin destination pairs, transfer via a hub incurs too great a time penalty. In 1991, seven out of the top ten intra-EU routes were 650 km or less and even the longer ones such as Paris-Madrid have no obvious intermediate hub. According to most of the studies, the High-Speed Rail services compete effectively especially on distances below 500 km. For the more price-sensitive less time-sensitive leisure market, rail can compete over distance up to 1000 km.

A clear majority of experts agrees that airport ground access by rail extends the catchment area of an airport and that this would not only be the case at major airports. That means also that catchment areas of airports being linked by HST are extended, giving the opportunity of a more equal distribution of air passenger transport demand, at least within areas where the catchment areas of several airports overlap. Connecting airports to the high speed train network could extend the catchment area of major hubs to around 250 km, or a one and half hour trip to the airport (which is currently a time for many people to allow to reach the airport from their house).

Additional effects of increasing catchment areas are cited as: increasing airline choice; direct flights; more competition between airlines; accelerating concentration at large airports and more air passenger flexibility. Concerning medium-size airports, HST transport access could provide the same opportunities as to major airports. Eventually airport rail access is going to cause a new distribution of air passenger transport demand from an agglomeration with a major airport to a medium-size airports.

A reallocation of air traffic from large to regional (small-sized) airports (outside an agglomeration) would be expected to be slow, also further development in regional air transport would continue, especially with “hub-by-pass’ flights. [38]

4.3.2 *Saving time*

As air traffic is concentrated at large (hub) airports, constraints come up, such as long walking distances and delays. Until now, although often predicted, no lasting passenger transport gridlocks occurred in Europe, which should not mean that such an event is out of question.

The idea behind hub and spoke networks is to allow a number of different flights to arrive at an airport around the same time, so as to allow connections with minimum delay and also to maximise load factor of the various aircraft. Replacement of direct flights by indirect flights via hub airports has resulted in a reduction in the average size of aircraft, since airlines prefer to run more frequent flights rather than have a more limited schedule using larger aircraft. Unfortunately, not only does this cause congestion on the ground; it also means that far more effort is necessary to control all the aircraft trying to use a limited amount of space. [20]

Airlines prefer to keep this way of operation, what is rather convenient for the passengers, but on the other side very time consuming. Of course low frequencies would have substantial negative effect on scheduling cost and waiting cost at hub airports and waiting times would be even higher. Passengers must wait at the hub airports for the connection flight, mostly longer than it would be necessary, since the flight co-ordination is less efficient and minimum connecting time is higher, especially at main hubs like Paris CDG and London Heathrow. Large airports have longer waiting times than the smaller airports (Frankfurt Main, Amsterdam Schiphol), even though one would expect shorter waiting times given the higher frequencies of services. HST is the solution to maintain the same frequency in less costly way for airlines and airports, while satisfying passengers' needs to have shorter waiting times and better flight co-ordination. With HST connection we could reach even higher frequencies and enable carriers to supply transport services to many combinations of origins and destinations at high frequencies and low cost. High frequencies obviously help to reduce waiting time at airports. However, waiting times do not only depend on frequency but also on the way departure and arrival times of flights are co-ordinated and on minimal

connecting times. Timetables of carriers result from large number of considerations and operational constraints

Passengers would also benefit from the fact that it wouldn't be necessary to make a detour via the hub airport implying an extra stop, since HST can operate between cities with secondary airports as well. Within Europe the smallest detours occur when Brussels is used as a hub airport. The choice for hub airports in Amsterdam, Frankfurt, London and Paris would lead to an increase in total passenger kilometres of 2-12 percent. [32]

Passengers prefer to reduce the waiting time at hubs, rather than the waiting time at the departure or arrival airport in order to save some travel cost.

4.4 The role of Airport

4.4.1 More airport capacity for passengers

Whenever there is a discussion on any air-rail issues, the major players mentioned are usually the airlines and the railways. The influence any air-rail intermodality has on the airport is sometimes regarded only as a by-product and not the key question in the matter. At the extreme, it can be said that the airports' role in the issue is to provide the HST station. The airports' stake in any air-rail competition or complementarity issue is at least as big as that of the airlines and the railways. Most major airports in Europe are privately owned and operate under the target of maximising profits. [23]

I don't think It is incorrect to say that in the not-too-distant past most of the regulatory side tended to think of airports as entities, largely provided by the State or State-supported, whose main aim in life was to ensure that adequate facilities were made available for our airlines. It was merely necessary for the airlines, both scheduled and non-scheduled, to refer to their dynamic industry, to the growth in travel they have anticipated and to their demands for more capacity to be provided at ground level, and for the regulatory side to ensure, at least in the case of State airports, that attempts were made to provide this capacity. Airports are, to a greater

extent than ever, commercial, competitive entities. They want to make money; they need more passengers to pass through. A fresh look is required at how we regard airports – and this applies in the area of provision of capacity, as much as it does to questions related to safety or of public subsidy or of other economic regulation by way of charges and taxes. The role of airports should be given more recognition, especially from passenger's point of view. [8]

Airports are no different from the airline, and are influenced and effected by the same constraints of capacity shortage. It might be argued that airport and airlines can be seen as one because of the direct link between them; one can not operate without the other. Even more than airlines, airports are affected by limitations on growth due to capacity or environmental constraints, because airlines have the option to change to a different airport. Therefore, it might be argued that the option of expanding airports' passenger throughput with the same runway and ATC resources and with almost no additional environmental impact simply by shifting traffic to HST is more tempting to airports than to airlines. Especially commercial activities, the crucial factor determining revenues is the number of people using the airport, not the number of planes. Commercial activities of airports add up to 40-50% of total revenues. [8] This number has enabled airports to lower their fees to airlines in real terms by increasing their charges over years by less than the rate of inflation. Airport operators wish to continue this trend for the benefit of their customers and our communities. However, as the aeronautical charges do not cover operating costs, it is in the vital interest of airport users that non-aeronautical revenue or commercial revenues should be encouraged to grow.

Considering the fact that most airports have already good connections to the land transport network, the possibility of an airport becoming a multi-modal hub serving planes, trains and coaches, is a real opportunity. In this sense, a connection to the HST network is a crucial element. It might be the case in the future that airports will have slots for trains as they do for aircraft.

At a total of 32 airports in 29 cities in over 15 European countries, there are currently or planned rail stations served by long distance rail link. This shows a

change from the traditional view that rail links to airports have the primary role of improving access from the city centre. If a hierarchy of airport-rail relationship had been constructed, the base level would be a city-centre to airport connection; then a rail system at airport or a through intercity service; and finally at the highest level, an airport to airport rail connection as is the case between Zurich and Geneva airports. In addition, there is a plan for HST connecting Basel and Zurich airports. The line will complete a HST network connecting Switzerland's three main airports. [23]

Intermodality with rail will produce significant capacity gains by transforming competition between rail and air into complementary between the two modes, with high-speed train connections between cities. We can no longer think of maintaining air links to destinations for where there is a competitive high-speed rail alternative. In this way, capacity could be transferred to routes where no high-speed rail services exist. More efficient, more rational use of airports will not obviate the need for increase in capacity. The fact is that new airport projects are few in number (Lisbon, Berlin, Paris).

To take place emphasis on aircraft railway substitution from the airlines' point of view since, it is believed, the adoption of this way of operation by airlines would allow better overall benefits especially to passengers and also to airports, railways and the environment. If this option proves viable to airlines and/or airports, then the private sector is likely to contribute to the investment needed in order to adopt this way of operation.

4.5 *Cleaner environment*

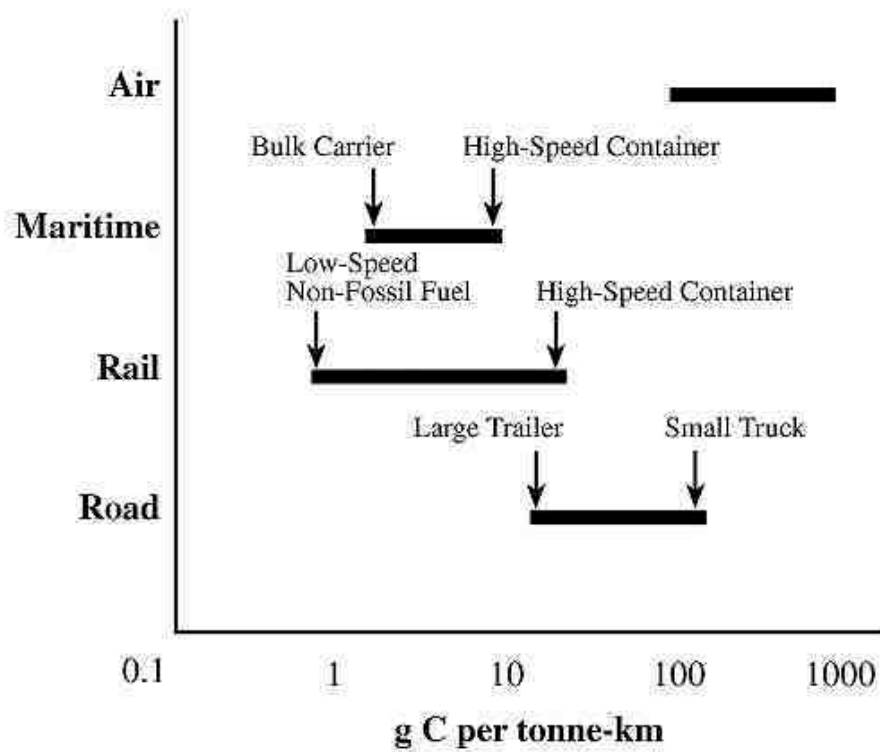
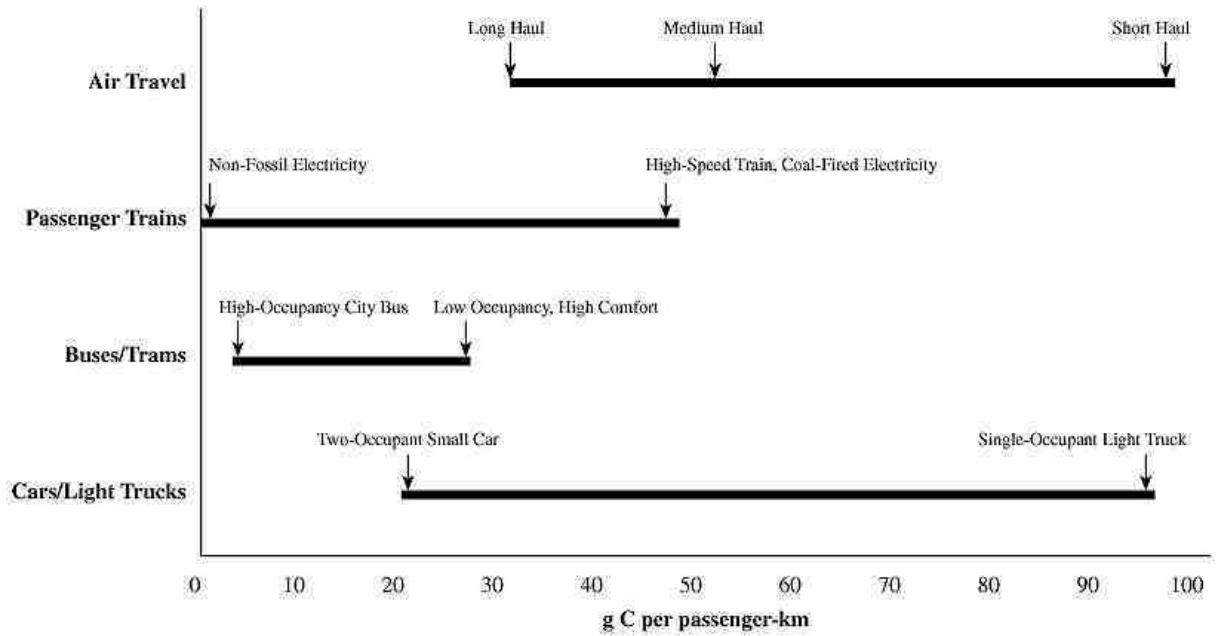
4.5.1 *HST - the best choice*

It is apparent that the air transport industry has an effect on the environment. This argument is reinforced as more research is carried out and as environmental awareness rises. The main environmental effects of air transport industry can be divided into four groups. These are noise, local air pollution, land use, and global

warming and climate change. The first three are local impacts, but as airports are usually located in or close to heavy populated urban areas, it means many people and businesses are affected. The study will take a closer look at noise and emissions, not meaning that the other two environmental effects are negligible or less important. The air industry operation is associated with different kinds of health problems according to research and the World Health Organisation. Technological improvements enable reduction in the environment impact of a given flight. For example, the estimated environmental cost of 1,000 passenger/km of Boeing-777 is 4,44 Euro while the figure for the smaller, but older Boeing-767 is 4.62 Euro. Fuel efficiency is expected to improve by around 1% per annum while passenger demand is expected to grow at around 4-5% per annum. If growth in demand could be met, the impact on the environment will intensify and will offset any technological changes that can reduce the actual impact per flight.

Regarding the question as to whether this reduction in the number of flights has brought environmental benefits depends on how the freed slots at the above airports are used. If they are used to accommodate growth in long haul flights, then the impact on the environment is probably negative. On the other hand, it can be argued that the shift of traffic and the availability of free slots for the long haul market could prevent, or at least delay, the need to expand the airport. Overall, this has a positive environmental impact. [23]

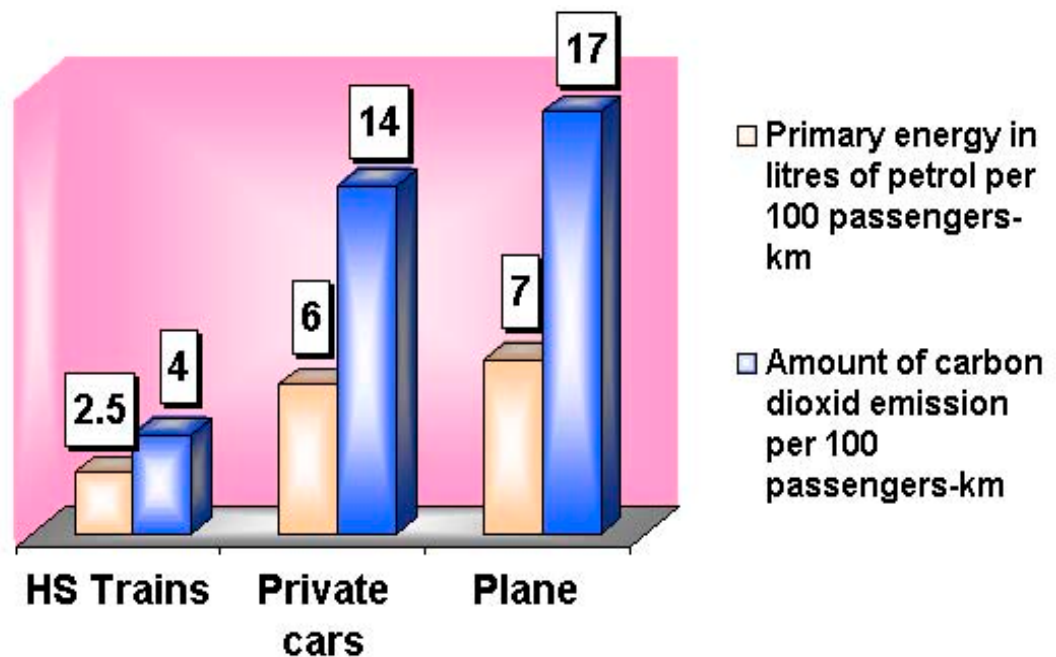
Aviation passenger mobility efficiency is very dependent on the type of aircraft, the configuration, the load factor, and the distance flown. Old aircraft use much more fuel per passenger-km than new aircraft of similar size. The required energy per passenger-km is in the range of 1.0 to 3.0 MJ per passenger-km, or about 30 to 110 g C per passenger-km. CO₂ intensity for rail transport also depends on factors such as energy source, type of locomotive, and load factor, and emissions of CO₂ range between less than 5 and 50 g C per passenger-km. [26]



4.2 Required C per passenger/km and tonne/km for different transport modes.

[26]

Emissions of CO₂ from all transport modes currently account for about 22% of all global emissions of CO₂ from fossil fuel use. In 1990, aviation was responsible for about 12% of CO₂ emissions from the transport sector. Aviation is currently responsible for about 2% of total global emissions of CO₂ from the use of fossil fuels. No matter how much has aviation progressed and how environmentally friendly aircraft are HST causes still less damage to environment per km travelled. The environmental costs of rail are no more than about ¼ those of the road mode. High-speed trains boast the lowest specific energy consumption, 676 kJ per passenger/km compared to plane with 1720 kJ per passenger/km. Energy consumption is a key driver behind three external cost effects: climate change, air pollution and up and down stream effects. [26]



4.3 Primary energy and CO₂ emission from transport

Data source: International Union of Railways

4.5.2 *Load factor*

As mentioned before load factor is one of the key elements determining efficiency of the transport mode. The load factor of transportation modes is critical to the analyses. A good example is a car occupancy, in particular, which can vary between 1 to 4, in Europe the average is 1.65 but in the US this value is generally less than 1.2 – which implies a significant margin in specific emissions relative to average occupancy. Occupancy levels for air, rail also vary significantly, but because of commercial pressures they are more likely to operate at higher levels than private road vehicles. European scheduled airlines typically operate at a load factor of about 70% and charter airlines at about 90%.

[26]

Opposed to air transport rail transport has very variant load factors on each track. As an example the Thalys traffic on Brussels-Paris had an average occupancy of 71% in summer 2001. It has dropped to only 58% if considering the entire Paris zone, including Roissy-CDG and Marne la Vallee. A much better load factor was recorded on Thalys route going to the south of France, representing an average occupancy of 82%. Once again Eurostar's occupancy on the Brussels-Paris link was 30% in average, much less than expected. [31]

4.5.3 *Noise*

Then there is noise. We all know that modern aircraft are quieter, weight for weight, than their counterparts of the 1960s and 1970s. Over the past 20 years the typical footprint of intrusive aircraft noise per movement around an airport has been reduced by 90%. In the Europe and US the number of air travellers has more than doubled, while the people affected by noise has fallen from about 20 million to less than 1 million, around 0.15% of the total population. We can not expect more dramatic reductions to be achieved in the next 20 years. However, impressive though such progress may be, it is plainly not enough to stem the strong opposition expressed by airport neighbours to any increase in capacity and therefore in traffic.

Modern aircraft are larger than the early jets, and by the immutable laws of physics, therefore make more noise. That can be defended, because an aircraft carrying 400 people is much more fuel-efficient than one carrying a quarter of that number. But to the person living around the airport, a noisy aircraft is a noisy aircraft, however efficient it is in technological terms. And there are many more aircraft today, particularly at busy airports. Even at airports where noise impacts, as measured scientifically, are decreased, there can be growing concern, because people expect a higher quality of life today, and they are less prepared to tolerate intrusive noise.

Rail is the best substitute for short-haul air travel. Especially if environmental constraints fuse with capacity constraints, like in the case of Schiphol. One of the first carriers to find a possible solution was KLM, which has decided progressively to phase out its domestic routes to the benefit of railways. A paper presented to a European Air Traffic Forecasting Forum estimated that even under favourable assumption for rail, high-speed train could substitute 10% of the European air passengers. [8]

Paris CDG has several destinations that could be replaced by HST. These destinations represent 16% of the scheduled traffic out of 800 flights departing regularly from CDG. This estimation is rather theoretic, based on the current network of HST lines in Europe and real data gathered from CFMU.

4.6 *Increased employment*

The most striking benefit, which a region reaps from its airport, is employment. The neighbouring communities, affected most by aircraft noise, are equally the main beneficiaries of an airport's social and economic effects: safe jobs, giving rise to increased purchasing power with a lasting snowball effect.

Turning to the catchment area, the people in the region of an airport are an extremely ambivalent user group, incorporating the strongest of contrasts while enjoying the benefits an airport brings. This group comprises not only direct users

of the airport but also those who are only passively affected by its presence in the region.

HST is the best way to increase airport passenger throughput, by which means many new jobs will be offered. A study by ACI Europe of the social and economic impact of airports shows that 1 million additional passengers create 1 100 jobs directly at the airport. Taking into account the indirect and catalytic effects, the total impact corresponding to 1 million air travellers is 4 000 jobs. 4 000 new jobs is no small argument on a continent where job creation is the Number 1 political goal. [8]

4.7 Constraints in the past

4.7.1 Late start

It can be asked why air-rail co-operation has not happened already, why we do not see major airlines buying into railway companies? Or why airlines do not use the HST instead of aircraft on routes where substitution is already possible? It will be suggested that the reasons are probably threefold: airline alliances, no environmental limitations and no extensive HST network. [23]

4.7.2 Airlines alliances

In the second half of the 1990s the airline industry was characterised by a frenzy for inter-airline alliances of various kinds. This “frenzy” is continuing into the new century as airlines seek new alliances or try to strengthen the ones they are in. It means airlines’ top management concern (other than everyday operation) is to position the airline in the alliances formation. This leaves no place for other drastic changes that involve introducing a completely new form of operations, such as a change that would transform the airline to an “Airailine” company. The situation is improving lately; more effort is shown from airline side. The best example is the Lufthansa and Deutsche Bundesbahn co-operation, also the latest services provided by KLM and SNCF.

4.7.3 *Environmental costs*

No environmental limitation - what is not exactly the case, since at some airports, strongly constrained by environmental limitations (Amsterdam), there are already strict charges. But at most airports, airline operations are almost non-affected by the environmental damage they cause. It is likely, that when airlines will face different charging structures and limitations on their operation because of their environmental impact, they will look further into the option of using HST to enhance their operations.

4.7.4 *Uncertainty*

The HST network in Europe is still evolving and expanding, but it is unclear, at least at present, what the network will look like and what cities will be included. More crucial, from the airline point of view, is the uncertainty involved with these projects, whether they will be built and when. Airlines as private companies can not operate under such uncertainties. The CTRL project might serve a good example. It was supposed to be completed by 2002, but it is now scheduled to begin operation in 2007, and even this is not certain. Projects proposed regarding London Heathrow airport connections to the HST network are even more uncertain, since they are only at the planning stage. Such conditions probably prevent a company like British Airways from seriously considering the use of HST at this stage.

4.8 *HST – part of the modern transport*

4.8.1 *Sustainability*

Intermodality is there a key element in any modern transport system. It underpins international trade and economic growth, while satisfying the requirements for sustainable development. Indeed, the intermodal approach has been identified as a major tool for reconciling the economic, social, and environmental dimensions of sustainability. Success in this regard requires an

overall vision and a balanced approach, as any integrated transport system has to be based on a rational and thorough cost-benefit analyses and a fair and equal treatment of complementary modes of transport. [33]

4.8.2 *Everyone gains*

Intermodal transportation is becoming more and more attractive as its possibilities for better mobility and sustainability become evident. Its better from the environmental point of view, better from the economic and trade point of view, from the transport operators point of view and especially from the passenger point of view.

Stated by US Transportation Secretary Rodney Slater: “The future system will be international in its reach, intermodal in its form, intelligent in its characteristics – using the power of technology, inclusive in its service – and innovative in its scope.”

5 DEMAND DISTRIBUTION MODEL

5.1 *Travel variables*

5.1.1 *Air or rail*

Even if the HST infrastructure is sufficient in many parts of Europe it is difficult to predict the number of passengers that would prefer rail transport to air transport. Passengers' choice is influenced by many variables. Most of the time there is no indication about passenger choice, there is no simple rule or equation according to which passengers behave when choosing between two transport modes. Of course there are indicators which help to clarify and model an exact situation, which vary according to the passenger type, geographical environment and climate, living standard, cultural differences and others.

Different passengers have different sensitivity scale to different variables. Variables could be grouped into three simple main categories.

Time – time is more important to a traveller than the distance. Passengers' sensitivity to this factor varies according to the purpose of the travel and other phenomena. Business travellers tend to be more sensitive to time than economy travellers. In terms of time we can not neglect the time travelled to the airport or rail station and time spent at the airport or station before the actual journey. All these factors are very important to passengers and could be decisive in a case of transport choice.

Expenses – money still talks. No need to mention that most of the passengers still look for the least expensive flight ticket, than try to adjust their need according to price. We are talking mostly about leisure travellers. Business travellers are rather ignorant to this variable, although the latest figures show that business travellers, especially the individual business travellers (from a small company or working for himself/herself) are becoming extremely cost sensitive on very short haul flights and switching to low cost carriers. To calculate total

expenses spent on the journey we should also consider expenses for the transport to/from the airport or station.

Attractiveness and quality – is a variable gaining more and more attention, especially in Western European countries and US. We need to mention few detailed examples, such as passenger comfort, punctuality, and influence from other transport mode, frequency, attractiveness of arrival and departure time and sensitivity of the transport mode to the weather conditions. When talking about passenger comfort it can add up to an almost unlimited list of possibilities. Among the most important are catering services, luggage handling, possibility to work on-board using lap-top or talking on cellular phone, advantages from mile acquisition, possibility to order taxi from board, magazines and different kinds of entertainment. Travellers seek quality transport more then ever before. Quality standard set by air transport is relatively high, although rail transport has more potential to reach the same level of comfort due to its many advantages.

Looking for the breakdown between air/rail mode there are many variables and differences to be taken into account. One of the main differences is the purpose of the travel. As already mentioned passengers have different preferences when travelling business or leisure. Preferences vary when travelling in the morning or late night.

5.2 Demand distribution model

5.2.1 Variable parameters

After the parameters influencing passenger transport choice were specified, it was necessary to describe the parameters and assign a value to each of them, in order to implement them into the demand model.

Value - all the factors used in demand model vary on 10-point scale, to allow the same importance to each factor. The main factors considered for the demand distribution model are the following:

- *Journey Cost*

Flight cost (AIR) – it is difficult to consider the cost in money value, we need to have a common attribute suitable for different short haul flights. The classification used in the IATA APT Rules (Air Passenger Tariff) offer ticket categories, according to which different ticket types could be graded. Since we are interested in short haul flights, mostly provided by medium size aircraft with no first class seats, only 7 different ticket classification are available (including low cost fare). In practice the ticket classification has a value on a 10-point scale, starting Low cost fare with the value 2.5 going up to Business Class Premium air fare with value 9,5.

<i>J - Business Class Premium</i>	9,5
<i>C - Business Class</i>	9,0
<i>D - Business Class Discounted</i>	8,5
<i>W - Economy/Coach Premium</i>	6,0
<i>S - Economy/Coach</i>	5,5
<i>BHKLMNQTVX - Economy/Coach Discounted</i>	5,0

The number of passengers choosing low cost carriers is rising all over Europe, It is important to add the 7th ticket classification. The ticket price is in most of the cases comparable with train fares.

<i>Low cost fare</i>	2,5
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There is a value jump between economy and business fares, since the prices of the business tickets are often almost the double of economy, both for air and rail mode.

Journey cost (RAIL) – the variety of the ticket types is smaller than in air transport. Although some railway companies are setting their fares using methods akin to the airlines' yield management policy; for example Thalys has already 7 ticket classes. To cover most of the railways we consider only the major classes, since not all railways practice the same pricing policy as Thalys.

<i>Business Class 1 / Class1</i>	5,0
<i>Business Class Discounted</i>	4,5
<i>Economy Class / Class2</i>	2,5
<i>Economy Class / Discounted Student Fare</i>	2,0

Cost to/from airport/station – the factor depends on the location of the airport or station (distance from the departure point of the passenger) and on the means of transport (public transportation/own car/taxi). The best comparison is made by converting the cost to EURO per km. There is no differentiation between air or rail travellers.

This variable is also between 1 and 10. The cost should not exceed 5 Euro/km.

Price	Value	Price	Value
0.5Euro/km	1	3Euro/km	6
1Euro/km	2	3.5Euro/km	7
1.5Euro/km	3	4Euro/km	8
2Euro/km	4	4.5Euro/km	9
2.5Euro/km	5	5Euro/km	10

- *Travel time*

All the factors concerning travel time (flight time, time to/from airport/station, and walking/waiting time) are applied in hours.

- *Competitiveness*

This corresponds to the influence in the decision making process from different types of plane/train or other mode of transport. In a two-hour slot how many other planes/trains leave from the same airport or station with the same destination? The highest number of planes/trains departing from the same station we considered was 10.

If there is one train/plane leaving in 2-hour slot from the same station/airport the value in the demand model is one, if there are 5 trains/planes the value is 5.

- *Frequency*

The value represents the number of planes/trains departing from the same airport/station with the same destination in a 24-hour period. To prevent overestimation it is essential to normalise the final number so as to remain on a 10-point scale. The highest frequency we have considered was 20 planes/trains in a 24-hour period.

- *On-board services*

As already mentioned this factor is a group of services such as catering services, luggage handling, possibility to work on-board using lap-top or talking on cellular phone, advantages from mile acquisition, possibility to order taxi from board, magazines and different kinds of entertainment. The factor has a value from 0 to 10, according to the services provided. There are 10 different classes of air and rail tickets all together, in this case it's easy to assign a value from 1 to 10.

Seat ratio

The difference in number of economy and business seats must not be overlooked when comparing the breakdown. Most of the aircraft flying on short-haul distances that could be replaced by HST services carry on-board 93% of economy and only 7% business passengers. This seat ratio is an average number of examined aircraft types:

A 320	12Business/138Economy	A 319	8B/116E
B 737-300	8Business/118Economy	B737-600	8B/102E
B737-700	8Business/118Economy	B 737-500	8B/102E

The situation is different for trains. HST carries 60% economy and as much as 40% business passengers.

Since the difference between air and rail is significant, the seat ratio was taken into consideration in the demand model.

5.2.2 *Passengers' sensitivity – fix parameters*

A questionnaire was undertaken in order to study the sensitivity of passengers to eight different travel factors (ticket price, price to/from airport/station, travel time, time to/from airport/station, walking/waiting time, frequency, competition, on-board services). Around 50 participants who answered the questionnaire were from EEC Bretigny, 20 international students and 30 French citizens, different age and sex. The questionnaire was undertaken in May and June 2002. Participants were asked to assign an importance to each travel attribute according to their travel purpose (economy or leisure). On a 10-point scale the results were the following. The higher the number the more sensitive passengers are to the certain factor.

Travel attributes	Economy	Business
Journey time (α)	5.81	7.73
Ticket price (θ)	7.53	3.56
Time to/from A/P or S (γ)	6.92	7.21
Price to/from A/P or S (ϵ)	4.92	3.13
Frequency (β)	5.54	6.36
Walk/wait time (δ)	6.34	7.02
Competitiveness (λ)	5.20	4.08
On-board services (μ)	4.54	5.98

5.1 *Passenger sensitivity to travel attributes*

Antonia Cokasova – May/June 2002, see questionnaire on p.101

According to the questionnaire passengers flying for leisure travel are most sensitive to the ticket price and the least sensitive to on-board services. Business travellers are the most sensitive to journey time and the least sensitive to price to and from airport or station. This questionnaire covers very specific group of people,

there is a high geographical sensitivity. It would be interesting to see the results if the participants were from different working environment and different part of the world (Eastern Europe or US). For example the results would most likely vary in Germany, since the population is very time sensitive, more than in France.

Since participants are mostly from France, when implementing passengers' sensitivity in the demand distribution model, it is better to consider origin destination pairs including a French destination such as, - Paris.

Demand equation

Once the travel factors and the passenger sensitivity influencing it were observed, the transport demand model or utility, was completed. The demand model of a certain transport mode has the following form: C is a total cost, T is total time and S is attractiveness and quality.

$$D = C + T + S$$

The first two factors have negative values, the smaller the value the better for the passenger. The total cost can be described as a sum of journey cost from departure "i" to destination "a" (C_{ia}) multiplied by passengers' sensitivity to journey cost (θ), and cost to/from airport/station (O_{ia}) multiplied by passengers' sensitivity to cost to/from airport or station (ε).

$$K = - [\theta C_{ia} + \varepsilon O_{ia}]$$

The total time is described as the sum of journey time (T_{ia}) multiplied by passengers' sensitivity to journey time (α), time to/from airport/station (A_{ia}) multiplied by passengers' sensitivity to time to/from airport or station (γ) and walking/waiting time (W_{ia}) multiplied by walk/wait time sensitivity (δ). Factors have negative value for the same reason as described before.

$$T = - [\alpha T_{ia} + \gamma A_{ia} + \delta W_{ia}]$$

Attractiveness and quality is the sum of frequency (H_{ia}) multiplied by passengers' sensitivity to frequency (β), competitiveness (P_{ia}) multiplied by passengers' sensitivity to competitiveness (λ) and on-board services (S_{ia}) multiplied by passengers' sensitivity to on-board services (μ). Attractiveness is the only attribute with a positive value, since the higher the quality the better from the passenger point of view.

$$S = \beta H_{ia} + \lambda P_{ia} + \mu S_{ia}$$

After comparing each factor separately the result shows a percentage of passengers choosing the examined transport mode. The form of equation is such that the model will always forecast passenger distribution between 0% and 100%.

5.3 *Practical examples*

Once all the variables are introduced, they can be applied to practical examples and real situations. As mentioned before it is better to choose a flight from Paris, since the examined group of people were mostly French.

5.3.1 *Paris – London*

According to airport statistics, this was the 2nd busiest route in Europe in the last few years, supporting 2,92 million passengers each year. [18] Passenger numbers changed following the introduction of the new Eurostar high-speed train passing through Channel Tunnel. It is one of the few OD pairs where HST and air can simultaneously be considered as viable travel options.

The following example is a simple travel model from Paris to London by air. There is a mix of economy passengers (73%, see seat ratio chapter) with economy/coach tickets and business travellers (7%) with business tickets. Economy passengers are taking the train to the airport with the average cost of 1 Euro/km, business travellers are taking a taxi, costing 2 Euro/km. The flight time is 72 min and there are two trains leaving from the same airport in a 2-hour slot with the same destination. The time to get to and from the airport is 54 minutes. All of the travellers have to walk

and wait at least 1 hour at the airport. Business travellers have much better pre-boarding and on-board services than economy. The frequency of aircraft is once every 2 hours.

For rail we also have a mix of economy and business passengers (60% economy and 40% business, see seat ratio chapter) with corresponding tickets. The other attributes remain the same, except for the travel time, which is 3 hours and the time to/from A/P or station, also the walk/wait time, which is 18 min for each.

Travelling by AIR:

	Economy	Business
C - Flight cost	5,5	8,5
O - Cost to/from A/P-S	1,0	2,0
T - Flight time	1,2	1,2
H - Frequency	2,0	2,0
A - Time to/from A/P-S	0,9	0,9
W - Walk/wait time	1,0	1,0
P - Competitiveness	2,0	2,0
S - On-board services	4,0	8,0

Travelling by RAIL:

	Economy	Business
C - Flight cost	2,5	5,0
O - Cost to/from A/P-S	1,0	2,0
T - Flight time	3,0	3,0
H - Frequency	4,0	4,0
A - Time to/from A/P-S	0,3	0,3
W - Walk/wait time	0,3	0,3
P - Competitiveness	1,0	1,0
S - On-board services	3,0	6,0

Passenger Sensitivity: Economy Business

θ - Flight cost	7.53	3.56
θ - Cost to/from A/P	4.92	3.13
α - Flight time	5.81	7.73
β - Frequency	5.54	6.36
γ - Time to/from A/P	6.92	7.21
δ - Walk/wait time	6.34	7.02
λ - Competitiveness	5.20	4.08
μ - On-board services	4.54	5.98

Implementing the values above into the demand equation the percentage of passengers choosing air transport is 43% and passengers prefer rail add up to 57%. This breakdown changes when any factor input changes.

5.3.2 *Paris – Brussels*

This was one of the busiest air routes prior to the introduction of the Thalys. Recently, high-speed train has replaced all the flights, since passengers had realised the time saving. Under the terms of agreement, Air France replaced its flights with chartered Thalys coaches between Brussels-Midi and Roissy-Charles De Gaulle and showed willingness to go in this direction rather than trying to compete directly. But it was also feasible because of the rail link being at CDG. Without this, it might not have happened.

In order to compare the air and rail breakdown we suppose that there are still flights between Paris and Brussels without a stopover. The flight time is 50 min, and the train journey takes 1h20. For ease of comparison, all the other attributes (walk/wait time, cost to/from airport/station, etc.) remain the same. The demand equation results in 34% for air transport and 66% for rail transport. In reality, it is impossible to measure, since as already mentioned the high-speed train is the only transport option.

According to these results, aviation should capture 34% of the passenger traffic. We can conclude that even if there is 34% of air share, it is not enough to keep the air market alive, since airlines stopped operating on this route. Of course the reasons to stop operation could have been various.

5.3.3 *Other destinations*

It is interesting to compare the value for breakdown between the European most constrained routes. According the CAA airport statistics and ICAO data, the routes supporting the largest traffic in passenger km's for last few years were the following.

1	London-Dublin	11	London-Munich
2	London-Paris	12	London-Geneva
3	London-Amsterdam	13	Copenhagen-Oslo
4	London-Frankfurt	14	Paris-Milan
5	London-Zurich	15	Paris-Madrid
6	London-Rome	16	London-Dusseldorf
7	London-Milan	17	Paris-Frankfurt
8	London-Madrid	18	London-Stockholm
9	London-Copenhagen	19	Copenhagen-Stockholm
10	Paris-Rome	20	Paris-Amsterdam

Out of the 20 busiest routes in Europe, 9 are above 1000 km, 3 routes are between 800-900 km and 8 are less than 800 km. As it will be demonstrated in chapter 4.5 in theory high-speed train can replace 40% of the 20 busiest routes. For less time sensitive passengers the percentage rises to 55%.

5.4 Distance and time limit

The question arising is up to what distance can high-speed train be considered as an efficient substitution to short haul flights? Most studies talk about distance between 500-800 km's, very much depending on passengers' sensitivity to different travel factors. But what if we are not familiar with the demand market, we don't know what kind of passengers we are dealing with, neither what are their needs and priorities.

Passengers travelling by air have to consider fixed time blocks, respecting their duration, mostly set by air transport. One of the major disadvantages of air transport to rail is the check-in time, asking the passengers to be at the airport much sooner before the actual flight. In general, it is one hour for economy travellers and about 40-min for business travellers, also depending on luggage.

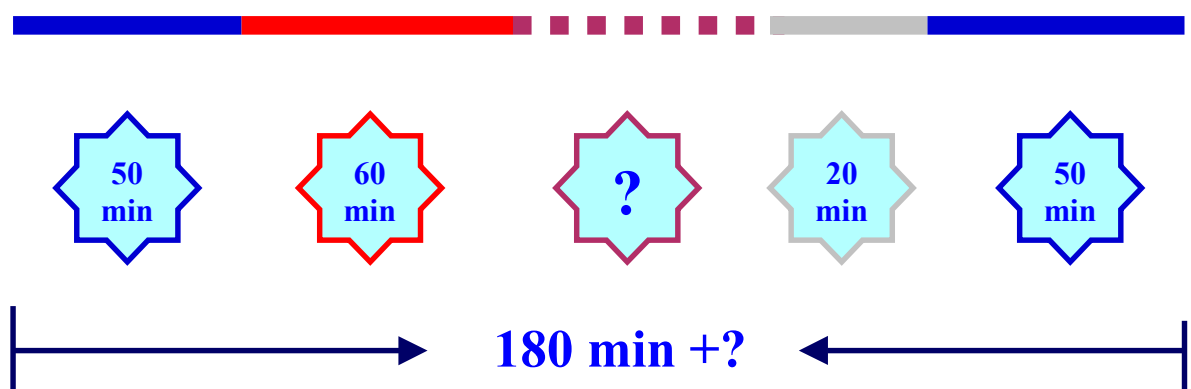
Passenger also has to consider the time spent to reach the airport, which is in many cases significantly longer than reaching a train station. Airports are moving

further and further from the cities they serve, reflecting that airports are not good neighbours, with noise and pollution being among the problems. But the move brings more problems – notably that of access. Different cities have different public transport and road networks. The time needed to reach an airport can be anywhere between 40 to 120 min in extreme cases (Paris CDG). In the case where road access is being used, this lack of predictability means that passengers generally have to plan for the ‘worst-case’ often leading to excessive waiting time in the airport prior to departure. On the other hand, for rail transport, a city centre with rail station can typically be reached within 30 to 90 min at the most.

Another fixed block to be respected by passengers is the time necessary to unload the baggage after landing, also the time required for passport check & customs, which will never be less than 20 minutes and in some cases, considerably more.

5.4.1 “Wasted time”

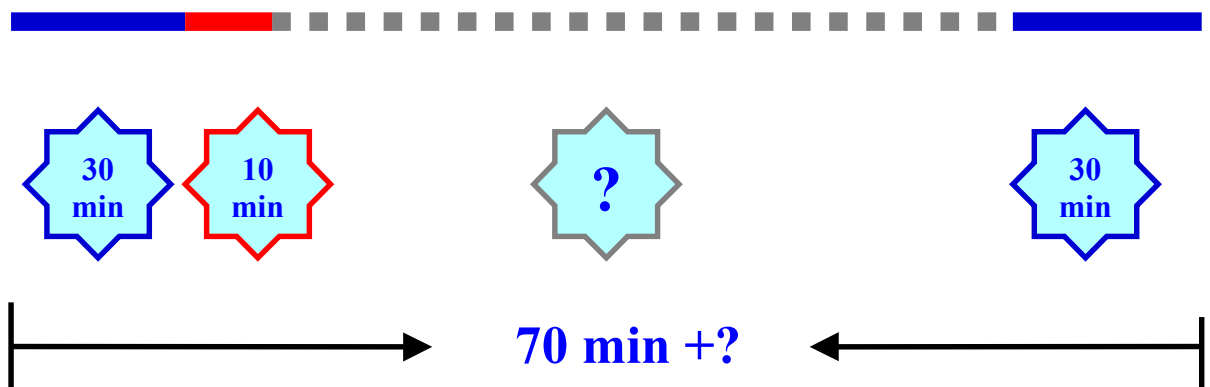
It is interesting to see the duration of “wasted” time at the airport or station. The following graphic shows the total “wasted” time when travelling, although it is not applicable in all cases.



5.2 Travel time by air

- ▶▶ Transport to Airport
- ▶▶ Time spent at the Airport (check-in, boarding)
- ▶▶ Flight time
- ▶▶ Awaiting for the baggage, customs + passport check
- ▶▶ Transport from the Airport

The total time “wasted” when travelling by air is at least 3 hours. Considering that 50 minutes for transport to/from the airport is a very optimistic estimation, for the most of the cases the number is even higher, especially for public transport.



5.3 Travel time rail

- ▶ Transport to Station (town centre)
- ▶ Time spent at the Station (check-in, boarding)
- ▶ Travel time
- ▶ Transport from the Station

The amount of time “wasted” when travelling by rail is about 70 minutes. As already mentioned this estimation can vary depending on many factors, does the passenger have a baggage to check-in, how far is he living from the airport, is the flight domestic or international and so on. Travelling by air the passenger can waste up to 200 min, and by rail transport up to 110 min

	Suburb 40 min	Center 80 min	Distant 120 min
Short Check-In No Baggage 30 + 10 min	80 min	120 min	160 min
Short Check-In Baggage 30 + 20 min	90 min	130 min	170 min
Longer Check-In No Baggage 40 + 10 min	90 min	130 min	170 min
Longer Check-In Baggage 40 + 20 min	100 min	140 min	180 min
Long Check-In No Baggage 60 + 10 min	110 min	150 min	190 min
Long Check-In Baggage 60 + 20 min	120 min	160 min	200 min

5.4 Air Transport - Check-in and travel time to airport.

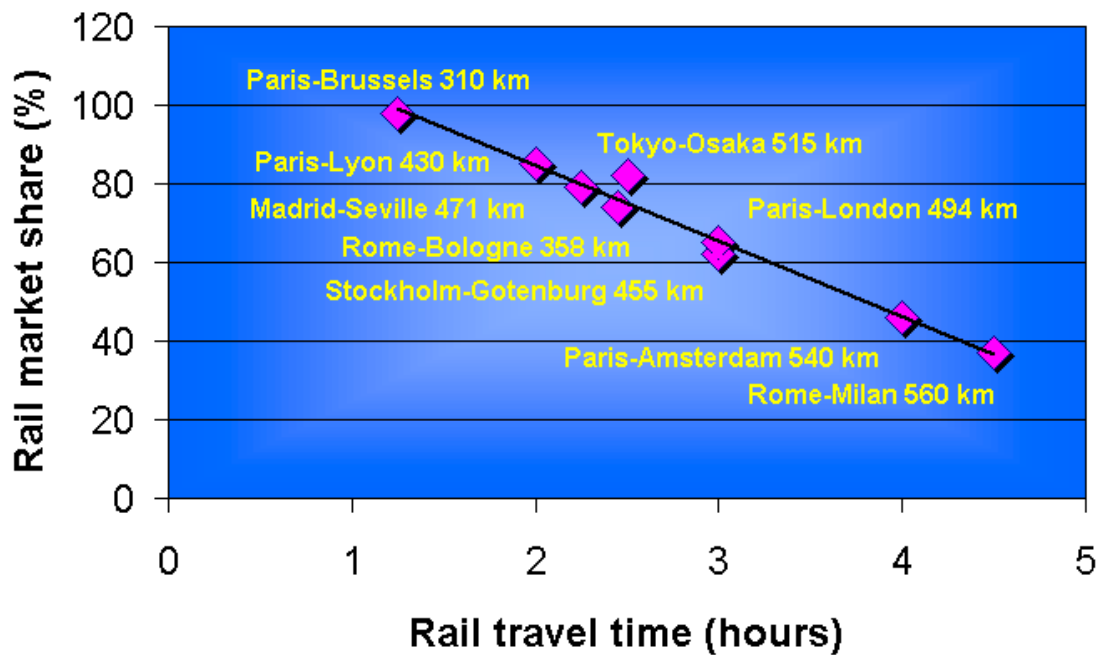
	Center 30 min	Suburb 60 min	Distant 90 min
Short Check-In 10 min	40 min	70 min	100 min
Long Check-In 20 min	50 min	80 min	110 min

5.5 Rail Transport – Check-in and travel time to station.

5.4.2 Time/distance limit

Examples show that HST competes with air services on 300-600 km distance. The breakdown of rail passengers decreases as distance growth.

**Curve of air/rail modal split
(distance between 300 and 600 km)**



5.6 Air/rail modal split

Source: International Union of Railways

To answer the question about the efficient distance/time substitution we need to set an average aeroplane/train speed.

Aeroplane speed = 800km/hour

Train speed = 270km/hour

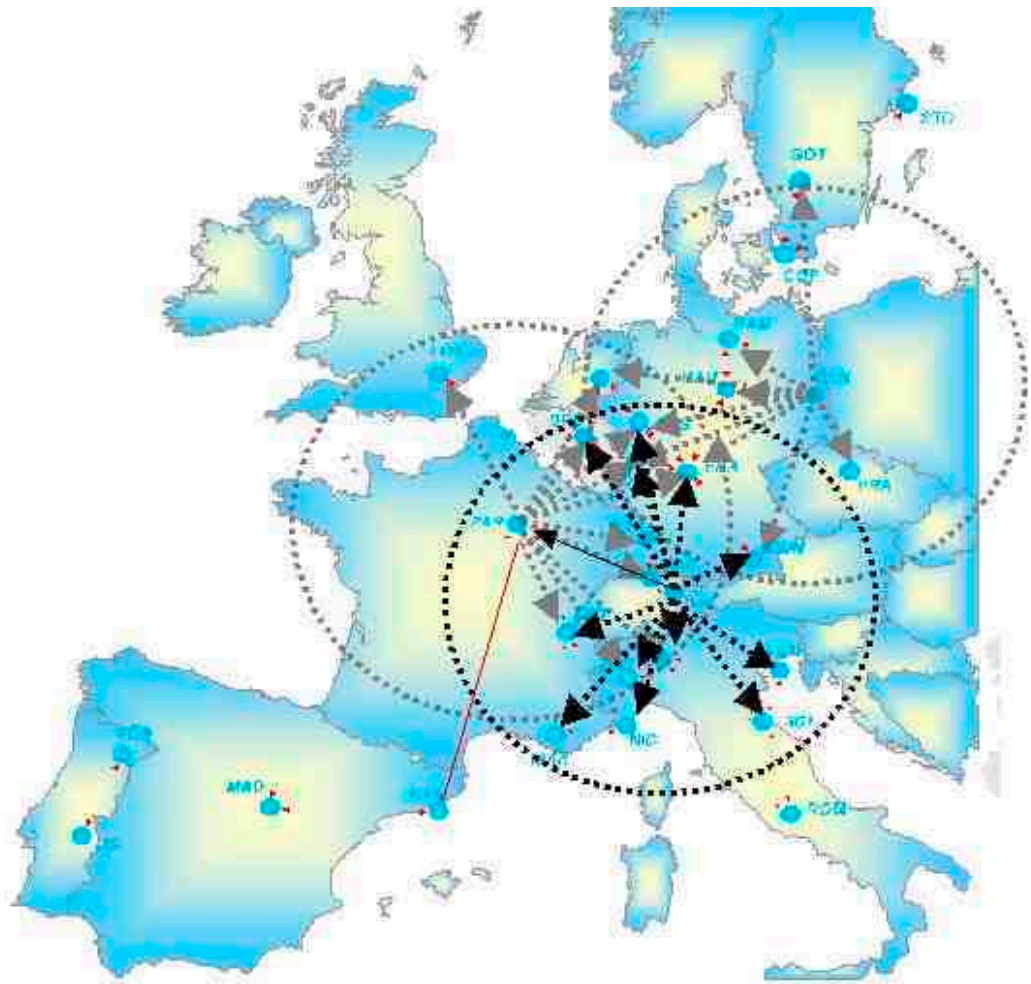
►► distance 750 km

“Wasted time” + Journey time = Total time travelled

by air: $180 \text{ min} + 56 \text{ min} = 236 \text{ min} = 3 \text{ hours } 56 \text{ min}$

by train: $70 \text{ min} + 166 \text{ min} = 236 \text{ min}$

According to simple equation, 56 min of flight time is the upper limit, any flight under this time limit will take longer by plane than by train. If aircraft flying less than 56 min is replaced by train, the total time travelled will be exactly the same. In terms of distance the limit is 750 km's. Any distance travelled under 750 km's has a shorter duration if travelled by train. Although this distance is considered to be a short-haul in the aviation business, in Europe the catchment area of 750 km's can connect significant origin destination pairs as seen below.



5.7 750 km's in Europe

6 HIGH SPEED TRAIN IN CONSIDERATION WITH OTHER DEMAND DISTRIBUTION PROCEDURES

6.1 *Long term alternative demand distribution scenarios*

High-speed train is not a comprehensive solution to airport congestion. Merging the benefits introduced by HST with other demand distribution solutions might lead to significant improvement of airspace/airport congestion. Study done by EUROCONTROL Experimental Centre PFE (Performance, Flow, Economics and Efficiency Unit) describes few very effective scenarios to ease airport congestion. Different alternatives are mentioned:

- Schedule smoothing
- Promotion of secondary airports
- Frequency reduction

6.1.1 *Schedule smoothing*

The main idea behind this alternative is moving flights to adjacent non-congested periods when the airport capacity is exceeded during peak hours. Such actions have already been taken in the U.S. by Continental Airlines who reduced the number of scheduled flights through the use of larger aircraft at Newark International Airport. Similar United Airlines began using larger aircraft and scheduling fewer flights to help address persistent delays in San Francisco. The effect of schedule smoothing is that the level of unaccommodated demand will be reduced as more flights may gain access to the system, provided that airlines can tolerate certain levels of “flexibility” in the schedule.

6.1.2 Promotion of secondary airports

Many airports lie close to each other, acting as potential competitors, although they should work in co-ordination, in order to serve the demand in the region. Some good examples are Basle and Mullhouse (Switzerland and France), J.F.K., La Gardia and Newark (New York and New Jersey), Bratislava and Vienna (Slovakia and Austria). In theory flights which are found to be constrained by airport capacity limits should be accommodated into the system using less congested airports. Considering this option many questions arise, such as transport communication between airports, or political constraints between airports of different countries.

6.1.3 Frequency reduction

Airlines fly frequently but with lower load factor causing en-route and airport congestion. Reducing the number of flights, while operating larger aircraft, will allow more capacity without enlarging airport infrastructure and still serving the same number of passengers.

Another possibility would be a different type of agreement linking the competitive carriers and increasing the size of the aircraft to keep the same supply of capacity. Otherwise, it could be an agreement joining two out of three companies, competing against the third one.

7 DIFFICULTIES AND SOLUTIONS TO HIGH SPEED TRAIN DISTRIBUTION

7.1 *Travel matters*

A traffic volume share of a given high-speed rail link to the airport has to be increased by every possible mean: integrated air-rail services; improvement of transport supply and services (frequency, quality, fares), profitability of rail links, framework of EU transport policy and long-term development. Further enhancement conditions are communication centres at airports; logistic facilities (check-in and luggage handling); more attractive rail stations and ticketing issues.

Other quantitative and qualitative matters within the transport supply to look at are check-in; reliability, modal integration; time; information. These are aspects, that rail management should be able to manage successfully.

It is necessary to do special effort to:

- Reduce cultural differences between railway and airline operators.
- Stimulate intermodal thinking among politicians, other decision-makers, and infrastructure planners.
- Liberalise railway operations according to market requirements for removing major differences in infrastructure cost coverage.
- Develop true interfaces between air and rail regarding their distribution, reservation, and information systems.
- Promote common standards on ticketing and clearing, baggage handling, and other carriage conditions including liability, with a view to secure immunity and providing the necessary regulatory framework.
- Identify best practices of both modes to be retained as intermodal ones.

[33]

7.1.1 Cost

What about the cost of intermodality? There are different arguments: apart from door-to-door suitability, infrastructure cost of course, and in particular cost in case of low transport demand volumes, which may be the case at the start of the operation.

Previously the cost of integration was perceived as being very high. Now as new technologies are developed both in operation and marketing the cost of doing business together are coming down and will do so for years to come.

The question “who is going to pay” is another sensitive subject. All the parties involved must realise that investments done today won’t bring any profit before tomorrow. They need to set clear boundaries and divide the expenses in a way that would more or less match with parties’ interest and involvement in intermodality.

A very wide variation in costs was found. At the one end of the scale are the 50 million Euro of Stansted and 60 million Euro for Manchester, both two-platform terminal stations in Britain. At the other end are the 280 million Euro for Charles de Gaulle which included a separate RER station, and 380 million Euro for Narita, Japan, although the latter unusually involves two separate stations, one for each terminal. [4]

However on the basis of information obtained, it should be possible to construct a comprehensive air/rail interchange on a through line to a reasonably high standard of design at a cost not exceeding 150 million Euro.

7.1.2 Customer satisfaction

More than the power of technology the success of intermodality will depend on the obsession of companies to work towards customer satisfaction. Traditionally it was assumed that demand for air transport was unlimited and supply limited. In a competitive environment the reverse is true. The intersection of the customer and

his relationship with the company is argued that only companies able to serve the customer first will survive today's turbulent and complex working environment.

The desired shift towards air/rail intermodality is described by the European Commission as a "transport with a human face"

So what are these "internal" customer service considerations? There are at least five areas with a great potential for co-operation

- Service standards and information system
- Integrated ticketing
- Extending networks
- Baggage handling
- Interlining

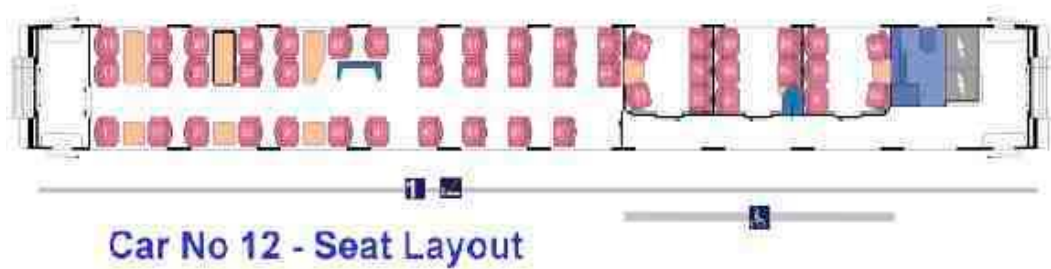
[30]

Service standards and information systems

In the past rail was considered as a low quality service transport. The perception of the rail product has considerably changed in the public's eye. HST and new airport express services deliver comparable services to the air product; comfortable seats, meals, lounges, etc. Passengers are in fact offered much more space than on an aircraft.

7.1 ICE Train “In-flight” Service is Business Class standard

Source: Lufthansa (FRA) –A case study for intermodality.



Co-operation between air and rail will strengthen the substitute effect of air and rail. For instance passengers can save on time as rail check-in in combination with a consecutive flight can often be done up to 15 min before departure, at least 45 min less than the alternative flight option.

Information to travel agents and at airports or in-flight magazines is another way of creating effective customer awareness. It comes at a very low cost compared to effect on potential demand. The railways also perceive this view. When asked to rank the obstacles to intermodality, SNCF said: first, lack of information. [30]

Integrated ticketing

Over time an intermodal standard for ticketing is required to enable fully seamless inter-changing of passengers. Both air and rail have very different standards and requirements for their tickets. All operators have conditions of carriage, limits of liabilities and required information of fare types, ticket deadlines, coding, etc. On the other hand, common e-ticketing applications could reduce costs if applied throughout the travel business (including car hire and hotels. [30]

Experience shows that at most interchanges there is a little integration between airline and railway systems in the fields of “real time information” and

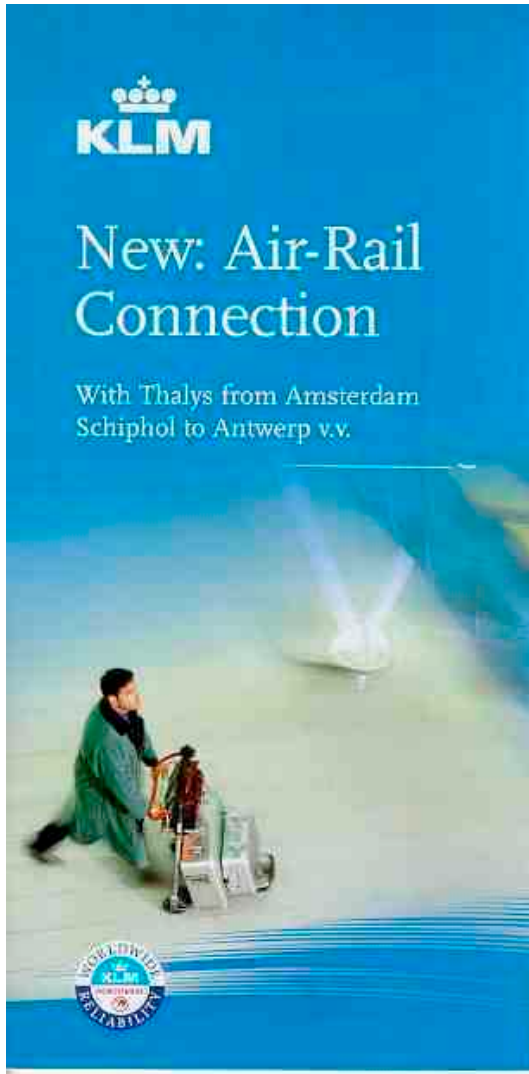
“ticketing”. While some attempts are being made, it is apparent that the barriers to fuller integration are costly to overcome.

In the case of real time information, it may not be necessary to have full integration in order to assist passengers. What is needed is the provision of separate information screens for aircraft and train departures alongside each other at the critical points on the passenger’s journey.

Integrated ticketing is a more fundamental requirement of passengers. They do not wish to have to make two separate transactions, one for the airline part of the journey, the other for the rail part. Currently some airlines and rail operators are co-operating to the extent of issuing through tickets, but with a requirement that passengers exchange one part of their ticket for another document, at the rail station. This is unsatisfactory from the rail passengers’ point of view, and tends to undermine confidence.

The only way to overcome this difficulty is to include the rail ticketing systems in the current joint airline CRS (computer reservation system). Technically, ways can be found to do this. The only difficulty is financial; rail operators are reluctant to consider paying the higher commission fees normally associated with air travel. [4]

One might think that through ticketing would be possible. It is possible but difficult. The major problem is already mentioned cost, where the reservation system charge, the settlement system charge and the commission are a significant burden on a low fare. The reservation system charge is a particular problem. EU competition legislation has been taken to mean that the same charge must be made for a 400 Euro flight as for a 20 Euro train journey – and the latter cannot stand that level of charge. [33]



7.2 Integrated tickets



Extending networks

With the completion of Trans-European Networks approximately in 15 years there will be a greater choice in destinations and transfer possibilities for the benefit of the travelling public. Airlines will use feeder rail services to hubs. As a result the market share of rail will increase on those routes or even replace air entirely.

Baggage handling

One other area where there is a lack of integration between air and rail is in baggage handling and check-in. It was noticeable that the great majority of air/rail interchanges had no system for baggage check-in at rail stations. Several indicated that they would be considering such a system, but with little enthusiasm.

Many issues of concern arise with luggage handling. The airlines have interline baggage tags that enable multiple carriers from one tag. The historical differences in security standards of railways would need to be overcome. It may be difficult on a system-wide basis, but examples already exist where this is done through special arrangements (e.g. Switzerland). [30]

Lufthansa and Deutsche Bundesbahn already offer seamless baggage handling, in co-operation with Fraport (Frankfurt Cargo Airport). Trains offer capacity for 6 special baggage containers, quick loading and unloading. Long-haul train station is linked to automatic baggage processing system. This way trains are handled like planes. A very well developed baggage check-in facility allows passengers to begin and end their journey at main railway stations in Switzerland. [22].

The biggest problem is not a check-in but in-town-check-out, where bags are checked from origin to destination station. In-town-check-in is expensive and difficult to get to work- in particular because of the relatively low throughput compared with an airport check-in, but in-town-check-out is far more difficult, because of customs problems in particular.



7.3 *Special baggage containers*

Interlining

The existing IATA intermodal interline agreement does not allow railways to sell airline tickets for given interline products. The market potential of interline products is however huge and would benefit both sectors. This will require hosting of rail systems in global distribution systems, common or standard ticketing, integration of billing and settlement systems and probably the use of a clearinghouse for the inter-carrier settlement. [30]

Passengers will make use of wider range of booking facilities through railway systems. In the event that through fare levels are required, existing anti-trust immunities would have to be extended to facilitate intermodal pricing setting.

7.2 *Planning stage*

7.2.1 Investment in air/rail interchange

It is essential that those responsible for planing either airports or railways should be aware of the possibility of future integration between the two, even if the time is not yet ripe for this. It follows that space should be left for additional facilities to be built at some point in the future, as has been done for example at Lyon and Manchester. But there are many cases where the existing infrastructure was planned several years ago, and opportunities were not taken, such as at Dusseldorf and Gatwick. It is very much more costly to change things now.

However, planners must also beware of building complete new facilities well before they are going to be required. Lyon is an example of a magnificent interchange, which is very much under used. It might have been better to build a simpler interchange now, with the expectation of upgrading it later as demand builds up (although taking into account the difficulty of constructing new facilities adjacent to tracks in use by high speed trains.)

The most fundamental issues of air/rail connections are:

- What are the main passenger markets to be served (air passengers, meeters and greeters, employees both at the airport and on adjacent developments)?
- What developments are likely at the airport e.g. new runways/terminals/
- What sort of rail services are required and to what destinations?
- What existing rail services are located in the area of the airport?
- What are the best options for connecting the airport to the rail network?
 - a complete new line
 - extending an existing line
 - a new station on an existing line plus a walk link or people mover
 - a loop allowing through services

- What are the best locations for airport stations relative to the terminals?

[4]

7.2.2 *Terminating or through rail line*

The evidence is clear that a through rail line gives a much better range of rail services than a terminating line. This is for two reasons:

- A through line can obviously allow services to /from the airport in two directions.
- The cost of running train services to the airport is much less if diverting an existing train service through the airport rather than starting a completely new service using additional rail vehicles provides them. Existing passengers not requiring the airport will be much less inconvenienced on a through line than by having to travel into the airport, reverse, and out again on the same track.

The most successful air/long distance rail interchanges: Charles de Gaulle, Frankfurt, Schiphol, Gatwick and Zurich, are all on through lines. In each case the stations have been constructed with platforms long enough to accommodate the longest train in normal operation.

Of course it will not always be feasible to construct a station on a through rail line such that it is close to the airport terminals. Compromise will always be required between the length of trough rail line to be constructed, and the location of the airport station(s). For example, at Dusseldorf, a new station is to be built on an existing rail line, which will be 2.5km from the airport, itself. On the other hand at Charles de Gaulle, the air/rail interchange has been built adjacent to Terminal 2, although it is some distance from Terminal 1. [4]

7.2.3 *Operated rail service*

The concept of rail service exclusively for airline passengers has been tried by Lufthansa at Dusseldorf and Frankfurt, and by Alitalia at Fiumicino, Rome. In each case the original concept has now been withdrawn because of lack of patronage. No long distance rail services at all now operate to or from Dusseldorf

Airport or Fiumicino. In other words, it does not seem possible to operate a viable long distance rail service on the basis of airline passengers alone. It also appears that airlines themselves are not the best providers of rail services.

As noted before the most successful long distance rail services are those with through tracks. Typically a wide range of destinations is offered, with frequencies of at least once per hour. Where frequencies are much below this, e.g. Satolas, a much smaller number of passengers will use the trains, because the waiting time between aircraft arrival and train departure (or vice versa) will be too long for most passengers. [4]

Having found that medium and long-distance air/rail services cannot be provided exclusively for airline passengers, it follows that the rolling stock used can also not be designed exclusively for airline passengers. Nevertheless, it is a general criticism of most of the airport rail services studies, that there is not enough allowance for the needs of air passengers in the design of the rolling stock.

The principle features missing are sufficient space for baggage and equality of height between the station platform and the train.

7.2.4 Maintaining safety standards

It is important to consider HST safety records in both Japan and France. Japan has had no fatalities on their high-speed rail lines in almost 40 years of operation. France can boast of a similar perfect safety record. The Federal Railroad Administration made numerous references to the excellent record when asked to examine the Florida Overland eXpress HST proposal. Additionally, it was noted that the linked construction of high-speed rail trainsets makes a rigid unit that is not prone to collapsing or telescoping like conventional railcars do in a derailment. This dramatically reduces the possibility of passenger injury. [29]

Air transport is one of the safest modes. However the media coverage of accidents could become the one factor curbing air traffic growth in Europe, even if the European Union can proudly point to the best safety record in the world. Shifting the balance between modes involves looking beyond the rightful place of

each particular mode and securing intermodality. Both air and high-speed rail have excellent safety measures compared to road transport (0.5 death per billion km for the rail by comparison with 12 for the roads), although a bulk in a system might appear considering rather security measures – integrated intermodal terminal. The terrorist attack on The World Trade Centre was a wake-up call not only for aviation but also for railways. They realised how vulnerable their system is, considering the fact that 1/3 of terrorist attacks world-wide target transportation systems. Intermodal terminal might appear more interesting to terrorists than a single transport terminal. The question of safety and security has to be taken very seriously.

7.2.5 *HST like LCC*

Surprisingly Low Cost Carriers have many similarities with HST services, such are:

- Homogeneous fleet
- Point-to-point instead of hub-and-spoke operations
- Frequent services
- Short-haul markets
- Rapid turnaround time
- Very high aircraft utilisation
- High load factor

When faced with competition with LCC, established carriers tend to lower prices. Delta lowered its fares in competitive routes terminating in Atlanta in response to competition by ValueJet. Is it going to happen if a HST enters the market? The answer depends on the relationship of railways and airlines. If the airline and the railway company will be in some kind of marketing agreement the answer is no. There is no competition without a competitor.

8 CONCLUSION

Railway companies and airlines are both in the transport business, but there exists a considerable gulf in both the philosophy and realisation of their operations. The two modes were born in different centuries; railway companies operate in the domestic area, while airlines operate far beyond their home country. What can be considered as a “long-haul” railway journey is short-haul in the airline world. The majority of railway customers are students and employees; airlines concentrate on business people and vacationers. Railway companies use their respective national language; the global language of airlines is English. Railway companies have a public service obligation; airlines tend to operate where they can make profit. Despite all the differences, air/rail intermodality brings together two of the fastest, high capacity and civilised forms of transport yet invented.

Aviation remains efficient regardless the physical relief of the land to be crossed whereas the train can only operate on rather flat ground. The train is tailored for short distances and passengers can get on and off at stations but this is impossible with the aeroplane. Due to their differences, capabilities and characteristics, the two modes fulfil the essential requirements of the market. Even in the 300 to 1000 km distance ranges, where the two modes do compete, they are also complementary because the air is faster and rather expensive and the rail is slower and rather cheap, thus addressing different market segments depending on how people are positioned in relation to the importance of time and money.

Constraints on air transport growth, cost-saving opportunities through substitution of short haul flights by rail and new technologies in the area of operation and ticketing, all lead to a business case for intermodality. Intermodality is above all a service to the travelling public. Passenger issues such as baggage handling and interlining require the active involvement of all stakeholders.

This thesis has demonstrated that High-speed train can be used to replace airline services up to 750 km's. The modal split depends on the passengers' sensitivity to different travel attributes. These attributes were closely investigated in

chapter 4. According to the results of a questionnaire undertaken in France, economy travellers are most sensitive to flight cost as opposed to business travellers, who tend to be much more sensitive to travel time. A demand distribution model was introduced, considering the sensitivity of passengers to different travel attributes. This model was applied for two origin destination pairs, Paris-London and Paris-Brussels. The breakdown of passengers choosing rail was 57% for the Paris-London route and 66% for the Paris-Brussels route.

But the work is only in its beginning, questions arise relating to issues in the operational as well as technical and economic domains.

As already mentioned it would be interesting to see a different mix of participants as well as a different questionnaire (asking passengers to rank their priorities instead of assigning an importance to each attribute). The work could be even enlarged to a third transport option (road), following the door-to-door transport scheme, as well as modelling Europe's 20th busiest routes in passenger km's.

Another step forward would be to closer examine the obstacles of intermodality on each side. Are railways ready to offer same or even better baggage handling as airlines? Should railways adopt some security measures practised by airports and airlines? There is a wide spectrum of future work, as much operational as technical. No matter how much these two transport modes resemble each other, the passengers perception of each mode is very different. Bringing the profile of air and rail modes closer together should be a priority for both parties.

The era of transport rivalry must become a thing of the past. If mobility is to be safeguarded in the long term, the modes will have to work together. In the long term, intelligent division of labour is indispensable, each mode covering that part of the transport chain for which it is best suited.

If we ask the high-speed rail world to list their priorities, the most likely answer will include noise constraints, infrastructure cost but definitely not intermodality. The Rail community is not going to initiate such a co-operation. Aviation is pushed from

many parties to keep the operation within certain limits, more constraints are set to aviation than to railways. That's why the initial move towards intermodality should come from aviation side.

As Martina Priebe said at the Eurailspeed conference in Madrid, air and rail together only transport about 11% of all passenger/km in the European Union. We should make it our goal that we can double this figure in about 15 years. Intermodality will be a key component of this strategy.

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Questionnaires:

SCENARIO No.1

You are travelling ECONOMY CLASS (travelling for leisure time, vacation) with luggage between two city pairs that are 600 km's apart. The most common way of transport between your departure and arrival city is either by plane or by high-speed train (TGV, Eurostar).

Please read the following variables and choose an answer that suits you the most (underline or highlight). Consider all the circumstances of the journey as one scenario.

1	TRANSPORT MODE	JOURNEY TIME	TICKET PRICE
	Air	1 hour 20 min	240 EUR
	High Speed Train	3 hours	140 EUR
		TIME TO/FROM Airport/Station	COST
	Air	50 min each way	6 EUR
	High Speed Train	20 min each way	3 EUR
		FREQUENCY (time length between 2 flights/journeys)	
	Air	2 hours	
	High Speed Train	1 hour 20 min	
		WALKING / WAITING TIME	
	Airport	1 hour	
	Train Station	20 min	

1. How much is the journey time influencing your decision of the transport mode (train or air)?

- entirely
- very much
- enough
- not much
- a little
- not at all

2. How much is the ticket price influencing your decision of the transport mode (Train or air)?
 - entirely
 - very much
 - enough
 - not much
 - a little
 - not at all

3. How much is the time spent getting to/from the Airport/Station influencing your decision of the transport mode?
 - entirely
 - very much
 - enough
 - not much
 - a little
 - not at all

4. How much is the cost spent getting to/from the Airport/Station influencing your decision of the transport mode?
 - entirely
 - very much
 - enough
 - not much
 - a little
 - not at all

5. How much is the frequency influencing your decision of the transport mode?
 - entirely
 - very much
 - enough
 - not much
 - a little
 - not at all

6. How much is the walking/waiting time at the Airport/Station influencing your decision of the transport mode.
 - entirely
 - very much
 - enough
 - not much
 - a little
 - not at all

After you have bought your ticket you have found out that there are many more varieties of the ticket (low cost airlines, conventional trains, bus, ferryboat).

7. How much are the different modes of transport and different types of plane influencing your decision?

- entirely
- very much
- enough
- not much
- a little
- not at all

The more expensive the ticket should the better on-board service (cold/warm meal, luggage handling, magazines, and newspapers...)

8. How much is the level of on-board service influencing your decision of the transport mode?

- entirely
- very much
- enough
- not much
- a little
- not at all

SCENARIO No. 2

You are travelling **BUSINESS CLASS** with a prepaid business ticket bought by your company (for a business meeting with no luggage) between two city pairs that are 600 km's apart. Your company is paying for all the travel expenses; no charge includes your personal budget. The most common way of transport between your departure and arrival city is either by plane or by high-speed train (TGV, Eurostar).

Please read the following variables and choose an answer that suits you the most (underline or highlight). Consider all the circumstances of the journey as one scenario.

TRANSPORT MODE	JOURNEY TIME	TICKET PRICE
Air	1 hour 20 min	350 EUR
High Speed Train	3 hours	200 EUR
	TIME TO/FROM Airport/Station	COST
Air	50 min each way	6 EUR
High Speed Train	20 min each way	3 EUR
	FREQUENCY (time length between 2 flights/journeys)	
Air	2 hours	
High Speed Train	1 hour 20 min	
	WALKING / WAITING TIME	
Airport	1 hour	
Train Station	20 min	

8. How much is the journey time influencing your decision of the transport mode (do not forget you are travelling for a business meeting this time)?
- entirely
 - very much
 - enough
 - not much
 - a little
 - not at all
9. How much is the ticket price influencing your decision of the transport mode (train or air) ?
- entirely
 - very much
 - enough
 - not much
 - a little
 - not at all
10. How much is the time spent getting to/from the Airport/Station influencing your decision of the transport mode?
- entirely
 - very much
 - enough
 - not much
 - a little
 - not at all
11. How much is the cost spent getting to/from the Airport/Station influencing your decision of the transport mode?
- entirely
 - very much
 - enough
 - not much
 - a little
 - not at all
12. How much is the frequency influencing your decision of the transport mode?
- entirely
 - very much
 - enough
 - not much
 - a little
 - not at all
13. How much is the walking/waiting time at the Airport/Station influencing your decision of the transport mode.
- entirely
 - very much
 - enough
 - not much
 - a little
 - not at all

After you have bought your ticket you have found out that there are many more varieties of the ticket (low cost airlines, conventional trains, bus, ferryboat).

14. How much are the different modes of transport and different types of plane influencing your decision?

- entirely
- very much
- enough
- not much
- a little
- not at all

The more expensive the ticket should the better on-board service (cold/warm meal, luggage handling, magazines, and newspapers...)

8. How much is the level of on-board service influencing your decision of the transport mode?

- entirely
- very much
- enough
- not much
- a little
- not at all

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Acronyms

ACC	Area Control Centre
ACI	Airport Council International
AENA	Spanish Airport and Air navigation Administration
AMOC	ATFM Modelling Capability
APATSI	Airport / Air Traffic Systems Interface
A/P	Airport
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
ATAG	Air Transport Action Group
AVE	Spanish Rail Operator
CAA	Civil Aviation Authority
CASA	Computer Assisted Slot Allocation (CFMU)
CFMU	Central Flow Management Unit
CODA	Central Office of Delay Analyses
CTRL	Channel Tunnel Rail Line
DB	German Railway Operator
ECAC	European Civil Aviation Conference
EEC	Eurocontrol Experimental Centre
EMTO	ECAC Medium Term Objective
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
GDP	Gross Domestic Product
HST	High-speed Train
IARO	International Air Rail Organisation
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
LCC	Low Cost Carriers
OD	Origin Destination
PBKA	Paris Brussels Koln Amsterdam
PFE	Performance, Flow, Economics and Efficiency Unit
PRU	Performance Review Unit
RER	Fast public transport train in Paris region
STATFOR	Specialist panel on Air Traffic Statistics and Forecast
SNCF	French Railway Operator
TGV	French High-speed Train

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