WP1 - Review of the current intermodality situation

Final version
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Executive Summary

The study “The airport of the future: central link of intermodal transport?” aims at analysing what could be the role of intermodal transport or intermodality between air and the other transport modes for the airport of the future; by elaborating European scenarios of transport network evolution by putting more focus on French and Portuguese ones, and identifying the social costs and revenues relative to these scenarios. Before determining what could be the role of intermodal transport for the airport of the future it is essential to review the current situation. Thus, this work package provides a state of the art of airport intermodality.

The first part of this study shows that there are two types of airport intermodal transports. The first type concerns airport access to the city centre while the second concerns the integration of the airport in the regional or national network of other transport modes. By providing an inventory of intermodality applications between air and other transport modes (bus and rail transports) and analysing the passenger demand for such intermodal transports this analysis underlines the importance of such a differentiation.

The second part of the work package deals with the policies and strategies towards intermodality. While the European Commission wants to promote the air/rail intermodality in order to reduce air and road congestion as well as air pollution different studies evaluating these impacts leads to divergent results. This would suggest that contrary to conventional wisdom, the business case for air-rail intermodal projects is not clear-cut. Despite the fact that the impacts of airport intermodality have not been yet clearly quantified, developing air/rail intermodality remains an objective for numerous European states. However, one of the major obstacles to a large development of intermodal transport is the funding problem due to the high level of investment required by the building of a new railway infrastructure. As the (limited) participation of the European Commission and of the national governments to the project financing will normally not be sufficient, the availability of private funding can have a large impact on the project realisation. This study underlines that the possibility of signing an exclusive agreement between airline and railway operators allows to guaranty that operators would be interested in this project and would be in favour of the infrastructure building. In addition, an exclusive agreement will also allow motivating the cooperation between both operators.

The agreements between operators concerning specific routes, relation between both operators can become complex. They indeed can be complementary in the market for connecting passengers on hub airport and in the same time rivals in the market of point to point travel. This complex situation is studied at the end of this document by focusing on the limit between competition and cooperation for both transport modes.
Acronyms

AEEL   Aviation Economics and Econometrics Laboratory
ANA    Aeroportos de Portugal, SA
ATC    Air Traffic Control
ATM    Air Traffic Management
CARE   Co-operative Actions of R&D in EUROCONTROL
CDG    Charles de Gaulle
ENAC   Ecole Nationale de l’Aviation Civile
HSR    High Speed Rail
HST    High Speed Train
IATA   International Air transport Association
TGV    Train à Grande Vitesse
WP     Work-Package
**Glossary**

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<td>Airport express train</td>
<td>Dedicated train linking directly airport to the city central station</td>
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<td>Consumer welfare</td>
<td>Benefit a consumer gets from consuming a good minus what he paid when buying this good</td>
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<tr>
<td>Consumer surplus</td>
<td>Difference between what a consumer is willing to pay and what a good actually costs</td>
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<td>Cooperation</td>
<td>Protocol between different transport operators aiming at coordinating their activities</td>
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<tr>
<td>Coordination</td>
<td>Action of harmonizing the transport operators operational activities in terms of schedules, frequencies, etc.</td>
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<td>Intermodal agreement</td>
<td>Agreement establishing the cooperation between different transport operators so as to provide combined transports for passengers and/or freight</td>
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<td>Intermodality</td>
<td>The use of several transport modes in one trip when transport modes are coordinated</td>
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<tr>
<td>Journey time</td>
<td>Duration of a trip not taking into account the access time to the airport, the railway station, etc.</td>
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<tr>
<td>Light rail</td>
<td>Transport mode utilizing predominantly reserved, but not necessarily grade, separated rail line. The vehicles are electrically powered.</td>
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<tr>
<td>Public transport</td>
<td>Collective transport with fixed routes and scheduled that everybody can use</td>
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<tr>
<td>Safety</td>
<td>Prevention measures taken to guard against accidents, technical failure, etc.</td>
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<tr>
<td>Security</td>
<td>Prevention measures taken to guard against espionage or sabotage, crime, attack</td>
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<tr>
<td>Suburban train</td>
<td>Train using the suburban railway network for connecting the airport and providing to suburban people a direct access from suburban rail stations to the airport</td>
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<td>Total elapsed time</td>
<td>Synonym of total travel time</td>
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<tr>
<td>Total journey time</td>
<td>Synonym of total travel time</td>
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<tr>
<td>Total travel time</td>
<td>Duration of a trip from departure city centre to arrival city centre including journey time for each transport mode used, airport and/or rail station access time, interconnection time, check-in time, etc.</td>
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<td>Transit</td>
<td>US definition for Public transport also called mass transit or public transit</td>
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<td>Travel time</td>
<td>Synonym of journey time</td>
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1 Introduction

1.1 Scope of the study

In a context of a fast evolution of the air transport market, the future of the Air traffic Management will not only be linked to the improvements in technologies, but also to the evolution of traffic flows. Despite the current difficulties in air transport, forecasts (as those considered by ACARE [Ref 1] or EUROCONTROL [Ref 24]) still mention strong traffic increases for years to come. What remains uncertain is the way this traffic will be spread out geographically. This will depend on three main factors: how competition inside air transport will evolve, how the infrastructure will deal with traffic increases and capacity constraints, and how competition and cooperation will be developed between transport modes. The evolution of these three factors and their interplay would shape what could be the “airport of the future”.

Given physical and nuisance constraints the extension of present airports may be difficult and new airports may have to be located far from city centres. Numerous questions can then be raised. Will these airports of the future be newly built airports or will they be located on the site of existing regional airports? Will these “airports of the future” become competitors of existing airports, or will they be complementary? Will the different transportation modes cooperate in developing intermodal transports? When trying to answer to these questions, it becomes essential to take into account the passenger perspective as well as the global transportation politics envisioned for the future. These elements will indeed mainly determine what could be the transport network evolution scenarios. According to the considered scenarios, impacts on the various economic actors could be different. What would be the effects on air transport actors in terms of activity, cost and revenue levels?

The study “The airport of the future: central link of intermodal transport?” aims at providing answers to all these questions when considering the global transport network. This constitutes an innovative aspect since the evolution of each transport mode was so far envisaged without taking necessarily into account the evolution of the other modes, and ignoring the possibility that the modes could be cooperative instead of being competitive only. An other innovative aspect of this study lies in the analysis of the intermodal transport as a way to tackle what could be the airport of the future. Indeed, this study considers the intermodality between all the possible transport modes (air, rail, road, bus, subway, etc.) by not only determining how the different modes can become intermodal transports, but also by identifying the impacts of the implementation of intermodal transport systems on all air transport actors. This means that we will not content ourselves with estimating the impact on passenger by estimating their cost by mode but we will identify the impacts in terms of traffic, cost and revenue on all the economic actors of air transportation.

The objective of the study is therefore to elaborate European scenarios of transport network evolution by putting more focus on French and Portuguese ones, and identifying the social costs and revenues relative to these scenarios.

1.2 Scope of the document

The first part of our document is centred on the concept of intermodality: how do we define intermodality, what dimensions of intermodality shall we be concerned with – considering that we are interested in intermodality only as far as air transport is impacted – and finally what is the demand for this kind of intermodal transport combining air and other modes. The second part is centred on the policies and strategies toward intermodality, and its impacts on the economy.
Chapter 2 presenting the first part of this work package is decomposed in three sections. Section 2.1 defines intermodality, presents the different types of intermodal transport at airports and enounces the necessary interoperability conditions allowing intermodality between different transport modes. Section 2.2 provides an inventory of the current intermodality situation in airports in terms of intermodal infrastructure and operators’ agreements. Section 2.3 deals with the demand for intermodality between air and the other transport modes by analysing the potential market and the demand features according to the type of intermodal transports.

Chapter 3 dealing with the second part of the work package is decomposed in five sections. As developing intermodality is an important objective of the European transport policies since Europe expects large benefits in terms of impacts on the environment, on congestion, etc., section 3.1 presents European policy concerning intermodal transports in airports. Section 3.2 deals with the future intermodal projects in airports that European states plan to develop. While section 3.3 studies the financing problems these types of project can present, section 3.4 presents the operator strategies when studying what are the limits between competition and cooperation between transport modes. After having studied the impacts of using intermodal transports in section 3.5, chapter 4 provides concluding remarks on this work package by identifying the lack in the literature concerning intermodal transport between air and the other transport modes.

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2 Intermodality: Definition, inventory and transport demand

2.1 Definition of intermodality

In a broad sense, intermodal transport can be viewed as the transport of goods and passengers by the use of several coordinated transport modes. More precisely we can find various definitions in literature:

- “Characteristic of a transport network which allows the use of at least two different transport modes for at least one single trip from origin destination” [Ref 54]
- “Characteristic of a trip which uses at least two different transport modes from origin destination” [Ref 54]
- “Characteristic of a nodal point which allows transfer between at least two different transport modes” [Ref 54]

Hence, the term intermodality can be used relatively to a system, a network, a trip, etc. and concerns all transport modes.

In the framework of the project “CARE II: The airport of the future: Central link of intermodal transport?”, we aim at determining the role of intermodal transports in the airport of the future.

If we consider the first characteristic of intermodality, which is the use of several transport modes in one trip, we can see that all trips made by air have to be intermodal trips since all passengers or goods have to go from their origin point to the airport.

Let us examine first the case of passengers. In this case, it does not seem particularly relevant to study all individual trips to the airport because they lack the second characteristic, which is the coordination of the transport modes. An individual car ride or taxi ride to the airport is tailored to suit the need of the individual but does not fit into the definition of intermodal transport.

Transport modes can be then considered as intermodal when they are collective, scheduled and when everybody can use them. For this reason, as far as passenger travel is concerned, we shall concentrate in this document on the analysis of intermodality on city-pairs between air and public transport modes (rail, bus, subway, etc.). Indeed public transports are collective and scheduled transports that everybody can use. This means that the term “public transport” can also be used for private transports made by rail, bus, subway, etc. if everybody can get a transport ticket. For instance, buses hired by the tour operators for carrying passengers from the airports to their hotel are not public transports.

We also need to distinguish between the trips where the second mode is used only to access the airport, with trips where the second mode is used for a substantial part of the journey. In the first case, the relevant modes to study are all public modes. In the second case, we will only take rail in consideration (and particularly high speed train), by assuming that the future large development of high speed rail in Europe, will be to the detriment of bus services development on long distance. Conversely, air-rail intermodality on city-pairs seems to offer promising opportunities for the future, and we shall focus on this subject for the rest of the paper, except in the case of airport access for which we will also study the bus-air intermodality. As explained previously we will not take in consideration in this document car transports although this transport mode is very often used, in particular for the airport access. A global analysis taking into account the road infrastructure used by public transport would deserve to be studied. This would require a complementary analysis which will not be possible in the framework of this study.

In the case of goods, since most of them are carried by roads (on short and medium distances) and sea (on long distances), intermodality developments have taken place so far mainly between those modes.
Air freight is still a minor part of freight transported, although the percentage in value is higher than the percentage in volume (air is used mostly for high value shipments or perishable shipments). Nevertheless, air cargo traffic is expected to significantly increase in the future. Indeed, BOEING [Ref 5] forecasts that air cargo traffic will triple over the next 20 years with an increase in the world's freighter fleet from 1,775 to 3,078.

So far, air cargo is carried to destination mostly by road. At the present time, giving railways a more important role by providing freight connections from producers to airports or from airports to customers has had little success. The European Conference of Ministers of transport concluded in 126th round table [Ref 26] that “volume of express cargo point to point service does not justify the high investments in rail facilities”. In addition, as customers are generally located close to airports the conference also concluded that “transport distances between the airport and customers are too short for rail to be competitive in comparison with road transport”. However, the development of the rail cargo is still to be considered by the CO-ACT Consortium which investigates the possibilities and concepts for the transport of time-critical cargo by rail [Ref 11]. This consortium justifies the development of the rail cargo by the fact that air cargo and time sensitive freight market will soon be in need of alternatives in terms of sustainability and cost. Today, the trucking of air cargo within Europe provides the most flexible and cost efficient means of shipment. Both the flexibility and the cost advantage of this means of transport are being threatened by increased congestion of the EU road infrastructure and impending road usage taxes. Security restrictions since 11 September have also constrained the movement of freight. After extensive study, the CO-ACT project has developed two concepts addressing the transport of time-sensitive cargo (esp. air-cargo) by rail. These concepts are a fast cargo train or a high-speed combi train (i.e. carrying passengers and freight). Even if such projects remains scarce it is not excluded that intermodality solutions between air and rail could be experimented in the future. Should we then focus on intermodality between air and road for freight? Unfortunately as for air/rail freight intermodality, the too few number of studies on air/road freight intermodality ([Ref 17][Ref 18]) does not allow us of performing a state of the art. In addition, the carriage of passengers’ luggage is not considered as freight in this study but as a part of the passengers’ transport. Air freight concerns all shipment carried by air (including mail) independent from the passenger transportation. As a consequence this work package focuses on the passenger activity although the freight transport will also be considered in the rest of the study.

To summarize, two main characteristics allow to define the intermodality:

- the use of several transport modes in one trip
- the coordination of the transport modes

### 2.1.1 Geographic intermodality

The role of an existing airport as a node of intermodal transport is partly exogenously determined by its geographic location. Several factors need to be taken into account, when developing a multimodal platform: the distance between the airport and the city centre, its geographic situation relative to other large cities (and their airport hubs).

In literature, the term “intermodal” transport applied to passengers using successively air and other transport modes is used equally for the airport access to the city centre or for the integration of the airport in the regional or national network of other transport modes. As the implications of both types of airport intermodality are different in terms of investment, passenger needs, operators coordination, transport policies, etc., it is essential to differentiate between them. In the rest of the document, we shall call type 1 intermodality, the intermodality concerning air rail links between cities and airport (airport access). We shall refer to type 2 intermodality when discussing the intermodality concerning
airport integration in the regional or national transport network.

**Type 1: Airport access**

In most airports of the world, bus services are used to provide access by public transport. Railway connections are scarce, especially in the United States. Indeed KAPER [Ref 41] explains that rail connection is recommendable for airports with more than 7 million of passengers per year. Heavy and light rail allow to handle massive and concentrated flows to and from major airports, whereas buses are more suitable in the case of smaller airports or more spread-out population (smaller or more dispersed flows).

The different types of access to airport are:

- **Bus** which is the more common type of collective transport to airport. Connection to airport by bus can be part of the city bus network but are in most of the case dedicated. In addition dedicated bus airport links can be express bus linking the airport to the city centre or regional bus linking the airport to other regional cities.

- **High speed dedicated or express train** linking directly airport to the city central station. KAPER [Ref 41] considers that such a “dedicated” system for short distance connections to the main urban area that airport serves, is the most important condition for a “successful airport rail link”

- **Light rail** which is a kind of tramway that can link airports as a part of a city public light rail network or as a dedicated link from the airport to the city centre

- **Subway link** which is one of the more common type of rail connection to airports. The links are very popular for airport employees but not much for passengers due in particular to the lack of space for luggage

- **Suburban railway** integrating the airport in the suburban railway network and providing to suburban people a direct access from suburban rail stations to airport

**Type 2: Airport integration in transport network:**

When another transport mode than air is used for replacing the air transport for part of the journey, the airport is integrated in this transport network. This integration is generally envisaged with the rail network. Different airport railways allowing this integration are:

- **Regional railway** allowing the airport to be directly connected to the regional railway network

- **High speed network** allowing the airport to be directly connected to the (inter)national railway network

The use of high speed network allowing reducing the journey time by train on city-pairs compared to the classic railway network, provides transport opportunities between a small number of major agglomerations at relatively short distances and can be consequently be a substitute for flight connections.

**2.1.2 Interoperability conditions**

The intermodal transports appeal is closely related with the level of complementarity between transport modes. This complementarity ranges from the presence of intermodal infrastructure inside airport area to all additional services facilitating the trip. The feasibility as well as the quality of intermodal transport are therefore closely linked to interoperability level between modes.
The COMMISSION DES COMMUNAUTES EUROPEENNES [Ref 15] and KAPER [Ref 41] establish that conditions for an efficient air/rail complementarity are:

- **Convenience**: the walking distance between rail and air terminal has to be as short as possible
- **Transparency**: ticket system and references like signs at the airport and rail terminals have to be clear so as to be easily understood by occasional users
- **Information**: the access to information has to be easy. Information in and outside trains have to be written in more than one language and staff have to be approachable. After landing the information on the rail transportation should be easy. Otherwise passengers will take the easier option, the taxi.
- **Accessibility**: the boarding to railway vehicles has to be easy for all passengers, including those with reduced mobility. In addition vehicles should have plenty room for luggage.
- **Security**: vehicles and terminals have to be controlled by cameras and staff
- **Timetable coordination**: For express train, light rail transit, suburban railway and regional railway the frequency has to be adapted to the passenger demand (high frequency in peak periods). For high speed train, timetables have to be coordinated with airline timetables so as to optimise the interconnection time between air and rail network.
- **Reliability and punctuality**: Passengers should count on the service offered. Hence if high speed train or airline is delayed, passengers have to be transferred on another flight or HST and if necessary accommodated
- **Booking**: Airline and railway company should cooperate to offer a common booking. When booking flight, passenger should be informed on public transport connections, and should have the possibility to buy a combined air-rail ticket
- **Check-in**: the luggage check-in should be possible at the origin of the trip i.e. at the railway station. IARO, ATAG and ACI [Ref 38] estimate that baggage handling is probably the major issue for air/rail intermodality and that full check-in in rail station would generate more passengers
- **Price**: Price of express train, light rail transit, suburban railway and regional railway have to be attractive so as to dissuade passengers to joining the airport by car and encourage the use of public transportation. The total price of a trip combining air transport and HST from an origin to a destination has to be enough low in comparison to the price of the direct flight so as to compensate the longer time trip and to be incentive for passengers.
- **Total travel time**: the total travel time by train should be shorter than the total travel time by air transport

### 2.2 Inventory

The efficiency of intermodal transports requiring to minimise the interconnection time (see section 2.1.2), infrastructure of modes complementary to air are located inside the airport area. In particular current applications of intermodality between air and rail are characterized by the presence of bus stops and of a railway station inside the airport area with facilities for joining the different transport modes. In addition, these applications are often characterized by cooperation agreements between operators.
2.2.1 Current European public airport access

2.2.1.1 Airport access

Buses using the road infrastructure for accessing the airport and not necessitating heavy infrastructure expenses have historically been the first public transport mode between the airport and the city centre. Because it is a cheap transport mode, airport access by bus still exists in all airports despite the existence of a rail connection.

Bus

In general all airports have connection to bus links, this is why it is difficult to provide a complete list of existing airport bus links.

Among bus links dedicated to airports we can list the examples of:

- **Barcelona buses**: The Aerobus service joins Plaza Catalunya to Barcelona airport in 30 min. and runs every 12 min. The journey distance is 12 km.
- **Belfast buses**: The Airbus service operates between Belfast airport and Belfast City Centre every 30 minutes. The journey distance is 30 km.
- **Berlin Buses**: the JetExpressBus TXL operates from Berlin Tegel Airport right into the heart of the Berlin old-new city and back in 20-25 min. The service runs every ten minutes from early in the morning until late in the evening connecting the airport with the government district, Unter den Linden and U Französische Str.. It also stops at a few main stations, where it is possible to transfer to Berlin's extensive underground, S-Bahn train and bus network. The journey distance is 7 km.
- **Brussels buses**: The Brussels bus company MIVB/STIB operates a bus link between the railway station Brussels-Luxemburg and the Brussels Airport in 30 min. The number of stops on this new "Airport Line" is limited to five. The journey distance is 15 km.
- **Bucharest buses**: Express Bus #783 connects Bucharest Otopeni International Airport with the center of Bucharest (approx. 40 mins) with stops at Baneasa Airport; Piata Presei Liberă; Piata Victoriei (subway links between Piata Victoriei and North Railway Station ); Piata Romana; Piata Universității; and Piata Unirii. The journey distance to the city centre is 20 km.
- **Copenhagen buses**: There are stops of 7 bus links in Copenhagen airport. The journey distance is 9 km.
- **Dublin buses**: Airlink is the Express Service to Airport bringing passengers direct from Dublin City Centre or Rail/Bus Stations to Dublin Airport in 30 min. The journey distance is 11 km.
- **Heathrow buses**: for the most towns around Heathrow airport, bus transport is the only real alternative to car. In addition, thanks to a vast marketing campaign, the demand of air passengers for bus express services to the airport has quickly increased of 50% between 1994 and 1999. In parallel of the express bus network serving all the United-Kingdom from Heathrow airport, there are local bus services. This large offer allow to bus terminals located in Heathrow airport to be the most frequented in United-Kingdom. 16% of travellers use this service. The Airbus links Heathrow Terminals with many London hotels and some main line rail stations. It departs every 20 - 30 minutes and takes approximately 1 hour. The journey distance is 25 km.
- **Lisbon Airport Buses**: The Lisbon public bus company CARRIS, operates a dedicated bus service to the airport (AeroBus). This service runs every 20 minutes connecting the airport to the city centre in 20 min. The journey distance is 8 km. Scotturb, a private bus company operates a
Airport Shuttle Bus Estoril, a dedicated airport service that connects the airport with Costa do Estoril, a tourism area in the outskirts of Lisbon.

**Paris Orly and Charles de Gaulle airports buses:** Air France operates direct bus link between Paris airports and Paris centre in 25 min. These “Air France buses” runs every 12 min. at Orly and every 15-20 min. at Charles de gaulle airport. Both airports are also connected to Paris public bus network. Jetbus links Orly airport to the metro station Villejuif Louis Aragon in 15 min. and runs every 12-15 min. Orlybus links Orly airport to Denfert-Rochereau square in 30 min. and runs every 12 min. The journey distance from Paris city centre to Orly is 15 km and to Charles de Gaulle airport is 26 km.

**Turin buses:** Bus service between downtown and Turin Airport takes 40 min. When running every 45 min, it has several stops en route including Porta Nuova main railway station, Porta Susa railway station, Via Borgaro and Caselle city centre. The journey distance is 16 km.

**Vienna buses:** Bus-Links Vienna Airport Lines operate to/from Vienna International Airport with Wien Schwedenplatz, Südtiroler Platz - Südbahnhof Wien / Westbahnhof and Vienna International Center. The service runs every 30-60 min and the journey time is around 30 min. The journey distance is 15 km.

<table>
<thead>
<tr>
<th>Airport</th>
<th>Buses</th>
<th>Journey time</th>
<th>Distance to the city centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barcelona</td>
<td>Aerobus</td>
<td>30 min.</td>
<td>12 km</td>
</tr>
<tr>
<td>Belfast</td>
<td>Airbus</td>
<td>-</td>
<td>30 km</td>
</tr>
<tr>
<td>Berlin</td>
<td>JetExpressBus</td>
<td>20-25 min.</td>
<td>7 km</td>
</tr>
<tr>
<td>Brussels</td>
<td>Bus MIVB/STIB</td>
<td>30 min.</td>
<td>15k km</td>
</tr>
<tr>
<td>Bucharest</td>
<td>Express Bus</td>
<td>40 min.</td>
<td>20 km</td>
</tr>
<tr>
<td>Copenhagen</td>
<td>Copenhagen bus</td>
<td>-</td>
<td>9 km.</td>
</tr>
<tr>
<td>Dublin</td>
<td>Airlink</td>
<td>30 min.</td>
<td>11 km</td>
</tr>
<tr>
<td>Heathrow</td>
<td>Airbus</td>
<td>1 hour</td>
<td>25 km</td>
</tr>
<tr>
<td>Lisbon</td>
<td>AeroBus</td>
<td>20 min.</td>
<td>8 km</td>
</tr>
<tr>
<td>Paris Orly</td>
<td>Air France bus</td>
<td>12 min.</td>
<td>15 km</td>
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<tr>
<td></td>
<td>Jetbus</td>
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<td></td>
<td>Orlybus</td>
<td>30 min.</td>
<td></td>
</tr>
<tr>
<td>Paris Charles de Gaulle</td>
<td>Air France bus</td>
<td>15-20 min.</td>
<td>26 km</td>
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<td></td>
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<tr>
<td>Turin</td>
<td>Turin bus</td>
<td>40 min.</td>
<td>16 km</td>
</tr>
<tr>
<td>Vienna</td>
<td>Vienna bus</td>
<td>30 min.</td>
<td>15 km</td>
</tr>
</tbody>
</table>

**Table 1: Journey distance and time of airport buses**

**Express train**

Eight airports are served by express trains in Europe. All these express trains offer a dedicated direct link between the airport and the city centre with a journey time not exceeding 1 hour.

These airports are:

**Heathrow airport in London (United-Kingdom):** Heathrow express, created in 1998, is a
rail express service operating at 160 km/h between the airport and Paddington station in London centre (24 km). The service is non-stop with a timetabled journey time of 15 minutes, running every 15 minutes.

Figure 1: Heathrow Express

**Gatwick airport in London (United-Kingdom):** Gatwick Express offers dedicated, high-speed travel between Central London and Gatwick Airport (44 km). Trains have operated directly to the airport since its opening in 1959. Airport Express has undergone a major service transformation with the introduction of a fleet of brand new trains at the end of 2000. The journey time is 30 minutes from London Victoria to Gatwick and the train frequency is 15 min. Gatwick Express carries four-fifths of all rail passengers to the airport, exploiting its advantage of offering the fastest journey time from the airport to central London.

**Stansted airport in London (United-Kingdom):** Stansted Express offers dedicated, high-speed travel between Central London and Stansted Airport (55 km), with trains departing every 15 or 30 minutes and with an average journey time of approximately 45 minutes.

**Malpensa airport in Milano (Italy):** Malpensa Express connects Malpensa International Airport to the centre of Milan (Cadorna Station) (50 km), with trains departing every half-hour, with a travelling time of 40 minutes.

**Arlanda airport in Stockholm (Sweden):** Arlanda Express created in 1999 is the airport express train between Arlanda Airport and the city centre of Stockholm (40 km). Escalator and lift allow going directly from the flight terminal down to the platforms at Arlanda. The journey time to Stockholm Central Station in the very heart of Stockholm is 20 minutes at a maximum of 200 km/h

**Schwechat in Wien (Austria):** City Air Terminal connects Schwechat airport to the centre of Wien (Wien-Mitte Station) (17 km), with trains departing every half-hour, with a travelling time of 16 minutes.

**Gardermoen airport in Oslo (Norway):** The Gardermoen line is the first Norwegian high-speed rail line, a 66km link from the centre of Oslo northwards to Eidsvoll, serving en route the Norwegian capital's new Gardermoen airport. The 18km journey from city centre to airport takes 19 minutes and trains operate every 10-20 min.

Figure 2: Gardermoen dedicated high speed train

**Fiumicino airport in Roma (Italy):** The express rail link connects the 27 km between the airport and the city centre in 30 min with trains every 20-30 min.
These express trains not only offer a direct link to the airport from the city centre but also allow long distance travellers to have access to the traditional railway system in the city railway station.

### Light Rail, Subway and suburban trains

When being linked to the light rail, the subway or the suburban network, the airport is a part of the urban public transport network. The aim is then not to provide the speeder transport mode to the airport but more to facilitate the airport access to a large number of citizens. The journey time for joining the airport will obviously differ according to the depart station.

The transport mode (light rail, subway, suburban train) will differ accordingly to the capacity needed for the passenger’s flow, and the type of service and commercial speeds required.

A light rail usually carries between 5 and 20 thousand passengers/hour, and its stations are spaced between 750 to 1500 meters. Since it runs partially in a non-dedicated infrastructure (mixed with cars and pedestrians) and it has several stops, the commercial speeds are lower than in heavy rail systems. Nevertheless it provides high accessibility within the urban area.

Subways and suburban trains are considered to be heavy rail systems. They are usually used for carrying between 15 and 30 thousand of passengers/hour. Stations are generally spaced for more than 1 Km, and they run in a dedicated infrastructure, thus achieving higher speeds. Although they provide higher mobility through speeds and passenger’s volumes, they give less accessibility.

In Europe, only 3 airports are served with a rail light transit with 2 in United Kingdom:

- **in Germany**: Bremen Airport.
- **in United-Kingdom**: Squires Gate Airport at Blackpool, London City Airport in London.

At the same time 8 airports are served with the subway.
in **France**: Orlyval in Orly airport in Paris.

in **Germany**: Schonefeld airport, tegel airport and Tempelhof airport in Berlin, Nürnberg airport.

in **Spain**: Barajas airport in Madrid.

in **the United-Kingdom**: London City airport and Heathrow airport in London, Newcastle airport.

Airports served with suburban rail links are:

in **Austria**: Schwechat airport in Wien.

in **Belgium**: Brussels National airport.

in **Denmark**: Kastrup airport in København.

in **France**: CDG airport (RER B) in Paris.


in **Italy**: Bari palese airport in Bari, Fiumicino airport at Roma, Caselle airport in Torino.

in **Netherlands**: Schiphol airport in Amsterdam.

in **Spain**: El prat airport in Barcelona, Jerez de la Frontera airport.

in **Switzerland**: Agno airport in Lugano, Klöten airport in Zürich.

in **the United-Kingdom**: Belfast City airport, Birmingham airport, Glasgow International airport, Gatwick, Luton and London City airports in London.

**2.2.1.2 Airport integration in transport network**

**Regional train**

The connection of airport with regional trains increases its appeal for travellers living at about several ten kilometres.

Airports served with regional rail links are:

in **Austria**: Graz airport.

in **Denmark**: Kastrup airport in København.

in **France**: Nice Cote d’Azur in Nice.

in **Germany**: Schonefeld airport in Berlin, Düsseldorf International airport, Frankfurt airport, Friedrichschaften airport.

in **Netherlands**: Schiphol airport in Amsterdam.

in **Norway**: Gardemoen airport in Oslo, Vaernes airport in Trondheim.

in **Spain**: Malaga airport, Valencia airport.

in **Sweden**: Arlanda airport in Stockholm.
in Switzerland: Cointrin airport in Geneva, Klötten airport in Zürich.


High speed network

The connection of a high speed train network with airports is a European specificity. Indeed, it does not exist anywhere in the world and concerns 8 European airports.

These airports are located on the networks of three categories of high speed trains: TGV (train à grande vitesse), Thalys International and ICE (Intercity Express).

The TGV is France's train à grande vitesse; literally "high-speed train" which has been developed and operated by SNCF, the French national railway company. Two French airports are connected to the TGV network: **Saint Exupery airport in Lyon** and **Roissy Charles de Gaulle (CDG) airport in Paris**. More than 50 trains leave CDG airport to 28 French cities, London and Brussels. For instance passengers can join directly CDG airport by rail from Lille in 55 mn, from Lyon in 2h05 and from Brussels in 1h40. At the same time, 40 trains leave Lyon Saint Exupery airport to 18 French cities (for instance Paris in 1h52, Marseille in 1h30) and to Milan (in 5 hours).
Thalys International trains are TGVs with modifications that enable them to run on several different types of power supply. The connection of Schiphol airport in Amsterdam (Netherlands), Brussels national airport (Belgium) and Roissy Charles de Gaulle airport in Paris (France) to the Thalys International network allow direct liaisons between the three European cities. Passengers can link CDG airport to Brussels in 1h40 and to Amsterdam in 2h50 by using the Thalys. In addition passengers can go from Schipol airport to Brussels in 2h27.

In Germany, the ICE high speed network is connected to Schonefeld airport in Berlin, Düsseldorf international airport and Frankfurt airport. The Fern Bahn (high-speed rail station) offers long-distance connections direct from Frankfurt airport, including Intercity Express trains. Direct connections are available to Stuttgart in one hour and 10 minutes, and to Cologne in just 57 minutes, using the brand new ICE dedicated line.
In Denmark, the NSB high speed network is connected to Kastrup airport at Copenhagen. Since July 2000, Denmark and Sweden are joined by a bridge, and it is possible to travel most conveniently by high-speed train from Kastrup Airport to Kristianstad Railway Station. The trip takes approximately 2 hours. The trains leave Copenhagen Central Railway Station, pass by Kastrup 13 minutes later and make a stop in Malmö before heading for Kristianstad.

### 2.2.2 Current operators agreements

With the creation of high speed links twenty years ago, air and rail transport modes have considered themselves as competitors to some extent. Nevertheless since the building of railway stations in airports, perspectives have been changing and airlines as well as railway companies have been realising that they could have common interest in developing bimodal products. Still nowadays only a few cases of cooperation between air and rail operators exist in Europe. Indeed, three different types of relationships can be identified between the rail and air services: first, competition between the modes on the same route, second, complementarity between the modes when the rail services offer connection from the city airport to the city centre (by HST, rail or metro services), or offer connection from the airport to nearby cities. This last relationship involving two different companies independent from one another, the railway and the airline can be described as cooperation. The rail services replace previous air services on short haul routes. In this case either one or two companies are involved, the railway and the airline, that operate under Code-Sharing agreement. Major information on the existing operators agreements have been obtained by A. COKASOVA from interviews with company representatives [Ref 13].

#### 2.2.2.1 AirRail services

In 1985 Lufthansa is the first airline operating special rail links like a flight between Frankfurt airport and Düsseldorf airport, and between Frankfurt airport and Cologne main station. These rail links use the Intercity Experimental (ICE) train. These airport express trains are only used by Lufthansa passengers who have the same service than for the air transport: air reservation system, luggage check-in in railway stations, drink and meal on board. Lufthansa stopped operating these airport express trains in 1993 because of the high related cost of operation. Nevertheless Lufthansa did not totally give up concluding a bimodal agreement with the Deutsche Bahn, which would be more viable.

That is why they accepted to offer in 2001 the AiRail Service in cooperation not only with the Deutsche Bahn AG but also with American Airlines, and Emirates airlines. With this new cooperation, Lufthansa can reserve seats directly on trains and does not need to reserve entire compartments as opposed to the previous cooperation.

AiRail Service is currently offered between Stuttgart Main Station (Hauptbahnhof) and Frankfurt International Airport and between Cologne Main Station and Frankfurt.

All passengers receive their boarding passes for connecting flights from Frankfurt immediately at the check in counters in Cologne and Stuttgart.

AiRail service enables all passengers between Stuttgart/Cologne and Frankfurt to check in their baggage at the stations and use the ICE high speed train service to Frankfurt (first class between Stuttgart and Frankfurt, second class between Cologne and Frankfurt for economy class passengers, first class for business and first class passengers) without having to carry their baggage themselves. The development of the product required not only the co-operation between Lufthansa and DB but also that of Frankfurt airport (Fraport) since the arrangements for luggage have to be treated in accordance to ICAO requirements before it is fed into the luggage system of the airport.

On board, Deutsche Bahn staff provides on board service comparable to the service offered on-board
European short-haul flights. In addition in case of flight cancellations, passengers have the right to board a train. The air ticket may be exchanged for a valid train ticket at either a Lufthansa or Deutsche Bahn counter.

### 2.2.2.2 TGV Air

In 1994, the TGV link between Lille and CDG airport developed an important market for rail. Air France and SNCF decided then to launch a first common experience on this destination: the “TGV AIR”.

This agreement holds that the transporting of international passengers between Lille and CDG is made by TGV while Air France cancels its flights between Lille and CDG. This organized bimodality does not concern the luggage check-in but allows passengers to buy tickets grouping international flights preceding or following TGV journeys. The TGV journey has a flight number and appears in the air reservation system. The TGV AIR product is therefore distributed and commercialised by Air France and by all travel agencies in the world. At the present time the display rules of reservation systems penalize the TGV AIR product since the display is done according to the journey time of the total trip. The offer TGV+aircraft does not appear on the first screen.

The TGV AIR product being a pre or post routing service, it concerns only some TGV links. Ten French links departing or arriving at CDG airport are TGV AIR products:

- Lille-Europe
- Lyon Part-Dieu
- Saint Pierre des Corps
- Nantes
- Angers
- Le Mans
- Poitiers
- Bordeaux

The ticket is composed of at least two coupons: one for the TGV journey, one other for the international flight. Nevertheless the coupon relative to the TGV journey can not be used directly as a TGV ticket since necessary information on tickets for rail and air are not the same. Indeed, as opposed to air tickets, rail tickets anticipate the seat number as well as the carriage number as soon as it is issued. As a consequence, information written on the TGV AIR coupon concerning the TGV journey are not sufficient and the passenger has first to go to a SNCF ticket office to exchange this coupon with a SNCF transport ticket. Passengers are therefore asked to come at least 20 min before the TGV departure for proceeding to this exchange.

The second drawback of the TGV AIR principle concerns the check-in. If the check-in can be made in Lille-Europe, Lyon Part Dieu and Saint Pierre des Corps stations, it is not yet the case in the other stations. In these three stations passengers get their TGV ticket as well as their boarding pass for the flight indicating their seat number in the aircraft. Nevertheless this check in does not concern the luggage check-in which has to be made at the airport. For the other TGV links, no check-in is made in TGV station and passengers have to check-in at the airport. In general the absence of luggage check in means that passengers have to get their luggage themselves on the train.

The correspondence time between the TGV arrival and the flight departure depends on the terminal of
flight departure and can reach up 90 min.

If the TGV AIR product increases the time spent in the TGV station and do not facilitates the check-in, it presents the advantage that the passenger is insured to go to the final destination in case of problem. SNCF and Air France have a replacement agreement linking them in case of disruption. Passengers can take an other flight or TGV in case of delays and are eventually accommodated.

SNCF also has TGV AIR agreements with other airlines such as United Airlines, American Airlines or Lufthansa. Each airline decides with SNCF which links to open to the TGV AIR product. American Airlines has concluded agreements with SNCF on links between CDG and Lille-Europe, Lyon Part Dieu and Nantes. The agreement concluded by Lufthansa with SNCF comprises the same links, and additional links to Le Mans, Angers, Rennes, Saint Pierre des Corps, Poitiers and Bordeaux. The agreement between United Airlines and SNCF concerns Lille-Europe, Lyon Part Dieu, Le Mans, Angers, Avignon TGV, Rennes, Nantes, Saint Pierre des Corps, Poitiers and Bordeaux.

### 2.2.2.3 Air France – Thalys International agreement

This agreement signed in 2001, holds that Air France stops operating flights between CDG and Brussels and that all Air France passengers are transported from Brussels to CDG via Thalys International trains.

On the other hand, Thalys International undertakes to reserve at least one carriage to Air France passengers and to increase its train frequencies.

This agreement differs from the TGV AIR agreement since travellers are welcomed on the Brussels station platform by Air France personnel and check-in in Brussels station for the whole journey (train+aircraft). Luggage is weighted and labelled in Brussels and luggage handlers help to get it on the train in a reserved emplacement but passengers have to carry it between the train and the airport check-in.

Thalys International has other bimodal agreements with other airlines such as American Airlines, Lufthansa, and SN Brussels airlines. The Air France, KLM and SN Brussels airlines are each engaged in a so called International Bimodal Transport Service (IBMTS) sub-contracts with Thalys International. They book entire coaches or seat blocks on three relevant Thalys routes (Brussels–Charles de Gaulle, Anvers–Schiphol and Paris (Nord)–Brussels National Airport). American Airlines books just space on Thalys trains.

### 2.2.2.4 Heathrow Express

Heathrow express, created in 1998, is a rail express service operating at 160 km/h between the airport and Paddington station in London centre.

Totally financed by Heathrow Express the service is non-stop with a timetabled journey time of 15 minutes. The carriages are equipped with air conditioning system and large places for luggage. Trains offer Standard and First class seats and an on board television.
Figure 6: Heathrow Express

Clients flying from Heathrow Airport are able to check-in for their flight at Paddington station, collect their boarding cards and ride Heathrow Express luggage free. Luggage travel independently from Paddington to the luggage carousel at the passenger final destination. Participating airlines are: British Airways, Air Canada, Lufthansa, British midlands, Finnair, Quantas, SAS, Singapore Airlines, SirLankan Airlines, Thai Airways International, Varig Brasil, LOT and Australian Airlines.

2.3 Demand for intermodality

2.3.1 Potential market

If air passengers are the main customers of air/high speed trains intermodal transports, they do not represent the only potential market for intermodality between air and the other rail transports (express trains, subway, suburban trains, etc.). Indeed by attracting numerous industries in their surrounding area, airports become economic centres with numerous employees. These employees work in the airport terminal or in the surrounding airport area. In addition, visitors accompanying air passengers, or coming for business reasons in the airport are also to be taken into account when evaluating the potential market.

The potential market is therefore related to the size of the airport in terms of passenger’s throughput and economic activities. KAPER [Ref 41] estimates that the bottom line for viable rail links is around 7 million of air passengers a year. In terms of volume air passengers form the most important group to focus on but employees present the main advantage of being more regular in time and space than air passengers.

The current market share of public transport to airports can vary substantially in Europe. For instance, the public transport market share in Oslo airport attains 60% (with 38% for rail) while this share is around 35% for the four big European airports (London-Heathrow, Paris Charles de Gaulle, Amsterdam Schiphol, Frankfurt).

More precisely, the market share of rail links to airport is for instance 20% for Stansted Express, 20% for Heathrow Express, 38% for Oslo's Airport Express which achieved this very high market share within two months of opening [Ref 41].

To summarize, the potential market of airport rail links are air passengers as well as employees and visitors.
2.3.2 Demand analysis

According to standard travel demand analysis, (see for example Quinet, Chap 4[Ref 58]) travel price and journey time (frequency is another dimension of time of travel) are the main elements of choice for a passenger, when deciding whether to travel and when choosing a travel mode.

As explained in section 2.1 we consider that luggage transport is part of the passenger demand for transport.

Travel price is easy to define in the case of air and rail transport. Data collection, however, is not always satisfactory, in order to allow future analysis of travel demand.

Passengers are sensitive to the total travel time which includes several parameters. For example in the case of an air journey, it would include: time spent going to the airport, time spent in the airport, time on the plane, time spent going to final destination, and also time lag between preferred time of arrival and actual time of arrival\(^1\). This last element is directly linked to the frequency of services. The more frequent the services, the shorter the lag. This is the reason why frequency, in demand analysis, is linked to the journey time component of the travel.

The simplest standard demand models that represent this choice are linear price-duration models, where the utility of the traveller depends on the total travel time and the price of the tickets. The traveller will choose the mode that gives him a larger utility:

\[
U(t, c) = \theta_t \times t + \theta_c \times c
\]

where \(t\) is the total travel time, and \(c\) is the total travel cost.

Mode \(i\) is chosen if \(U_i > U_j\)

Usually faster modes are more expensive and therefore the choice will depend on how sensitive to time the passenger is.

From these model we derive the “value of time”, which can be defined as the value of one hour of travel time: it is the price the traveller would be willing to pay in order to decrease its travel time by one hour.

\[
V_t = -\frac{\theta_t}{\theta_c}
\]

Another simple (and quite similar) way of putting it is to compute the generalized cost of travel. The mode chosen is the mode with the smaller generalized cost.

The generalised cost takes into account as well the ticket fare than the value of time for the passenger converted into monetary value:

\[
C_g = p + v \times t
\]

Where:

\(C_g\) is the generalised cost

\(v\) is the passenger value of time

\(t\) is the transport journey time

\(^1\) This last element is sometimes called “scheduled delay” in economic papers
The indifference value $v_0$ between two transport modes (1 and 2) is the value of time for which the passenger is indifferent between taking one of these modes i.e. for which the generalised cost is the same. $v_0$ is such as $p_1 + v_0 \times t_1 = p_2 + v_0 \times t_2$.

$$v_0 = \frac{p_2 - p_1}{t_1 - t_2}$$

In Figure 7: Generalised cost vs. value of time for journey in aircraft, HST or classical train, $v_0^1$ is the passenger indifference value of time between travelling by classic train or by air, while $v_0^2$ is the indifference value between travelling by HST or by air.

Figure 7: Generalised cost vs. value of time for journey in aircraft, HST or classical train shows that the presence of the high speed train increases the indifference values between air and rail transport modes.

This is of course only a simplified approach to the problem of mode choice, but is gives a simple framework of analysis to modal split. If one parameter changes (price or time) we can compute easily the new mode split between travel modes. For minor variations in the attributes (time and cost) this kind of models gives satisfactory results. More sophisticated models use non linear utility functions, (see BLAYAC and CAUSSE [Ref 6]), consider several parameters of time, and also considers that the value of time is not a constant but a function (see SCHNETZLER [Ref 63]).

So far, only time and price have been taken into consideration; in fact other dimensions can play a role in the choice made by the passenger. IATA lists other complementary elements of choice, related to quality of travel mode [Ref 39]:

- Connection issues at interchange points
Comfort and on board services
Service integration between modes or between operators
Information services
Security, reliability and delays

These elements will be more or less important according to the travel motive (business or leisure). The passenger demand would then depend upon a subtle arbitrage between the total journey price, time and the other elements linked to attractiveness and quality.

Indeed as explained for example COKASOVA [Ref 12], leisure passengers are the most sensitive to the ticket price and the least sensitive to the on-board services while business travellers are the most sensitive to journey time and the least sensitive to price. The latter will therefore tend to prefer faster transport modes when possible, even with higher prices, all other things being equal. This is reflected in their values of time, which tend to be quite lower for leisure traveller than for business travellers.

For business travellers, the analysis can be complicated by the fact that they are not usually paying themselves for their tickets. In this case, the choice will generally be made by their employers, who will have to maximise the profit they derive from the trip (balance between hourly cost of employee, and price of ticket).

As far as employees working in the airport area are concerned, TCRP [Ref 66] observes that factors influencing their use of public transportation are:
- The availability of transit service at employee residences
- The accessibility of the employee’s worksite to transit service
- The extent of employees working in non-traditional work hours
- The availability and cost of parking for employees

According to TCRP [Ref 66] 20 to 55% of employees at an airport do not work in the terminal area which illustrates the extent of employees’ dispersal inside airport area. That is why the existence of a transit service stopping at employees’ workplace is essential for these employees.

In general, passenger preferences for using rail mode to join an airport will be different if the passenger only considers the train as a way to access the airport (as with express train, suburban links, etc.) or if the passenger considers the train journey mode as an alternative to the air journey mode for linking two cities (with high speed train).

2.3.3 Demand for airport access

In their analysis of the demand for rail travel to and from Manchester and Stansted airports, LYTTHGEOE and WARDMAN [Ref 47] show that rail demand elasticities differ between airport travellers and other rail travellers. This means that expectations of rail travellers are not the same if they use airport rail links or if they use rail transport mode for travelling inside or outside the country.

When differentiating “Outward travellers” which are British residents travelling first to the airport and returning from it, from “Inward travellers” which are overseas residents travelling from the airport and then coming back to it, LYTTHGEOE and WARDMAN [Ref 47] estimate their related demand elasticities. They conclude that inward travellers are less sensitive to the rail journey time than outward travellers and at the same time less sensitive to the price. Indeed, inward travellers have
generally the information about alternatives to the rail service and although car hire is an option, the competition between rail and road is less important than for outward travellers. Nevertheless they can also choose taking taxis or buses. The lowest level of competition between car and rail for inward travellers also explains that they are less sensitive to an increase in rail journey price than outward travellers.

Nevertheless the proportion of rail users can vary substantially between airports of a same country because of the different characteristics of residents. Hence when observing three U.S. airports, TCRP [Ref 66] observes significant differences in the mode shares for airport ground access. While non resident air passengers on a business trip represent the highest proportion of rail users to Reagan airports, this is not the case in Boston airport where the resident air passengers on a non-business trip represent the highest proportion of rail users. This difference can be explained by the large student population of the Boston area which is a significant component of the resident non-business air passengers using rail to access Boston-Logan airport.

The importance of differentiating inward from outward travellers is also underlined by TCRP [Ref 66] which states that in the non-home area, the share of public modes used to go to the airport is nearly twice as high as in the home area. Hence this study would tend to show that the residency status of the traveller is relevant to the propensity to choose a ground access mode other than the automobile. However, it is important to note that the finding was concluded from a study undertaken in US. In Europe, the greater propensity of non-resident air travellers to select public transport modes can be illustrated by looking at the rail market for two London airport: Gatwick and Heathrow. Rail services in Gatwick capture nearly 40% of non-resident airline passengers and only 20% of resident airline passengers. In particular residents travelling for leisure have a low rate of rail use, mainly because of the high-priced Gatwick Express which only has 5% market share of London residents. Analysis of Heathrow market segmentation shows similar results. The market share of public transport services is higher among non-resident air travellers than among resident air travellers.

To summarize, the residency status of air passengers is relevant to the propensity to choose the rail mode instead of the automobile to access the airport. The market share of airports’ dedicated public transport would seem to be higher among non-resident air travellers than among resident air travellers.

### 2.3.4 Demand for air/HST intermodal transport

#### 2.3.4.1 Competition between rail and air: modal split

**Time and prices**

As explained in the demand analysis section, modal choice depends on several parameters, the two most important ones being total travel time and price. Passengers arbitrate between faster (and more expensive) modes and slower (and cheaper) modes.

In order to model this choice, the value of time of the traveller can be estimated from empirical data on existing journeys. Once known, the value of time can be used to compute generalized cost for different journey on different modes.

Values of time are regularly estimated, using empirical travel data, for different types of routes, or for different modes (air traveller have a higher value of time than rail travellers, or than the average in the population. The currently used values of time in France for infrastructure planning are in the table below:
WP1 - Review of the current intermodality situation  
CARE II: The airport of the future: Central link of intermodal transport?

Ref.: M3S/ATM/CARE-AIRCIT/EEC/WP1/4.0

Table 2: Value of interurban time per traveller
Source Commissariat général du plan 2001 [Ref 14]

<table>
<thead>
<tr>
<th>Mode</th>
<th>pour des distances inférieures à 50 km</th>
<th>Pour les distances comprises entre 50 km et 150 km et 400 km</th>
<th>Stabilisation pour les distances supérieures à 400 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route</td>
<td>8,4 €</td>
<td>50 km &lt; d VDT = (d/10+50).1/6,56</td>
<td>13,7 €</td>
</tr>
<tr>
<td>Fer 2° Cl.</td>
<td>-</td>
<td>150 km &lt; d VDT =1/7(3d/10+445).1/6,56</td>
<td>12,3 €</td>
</tr>
<tr>
<td>Fer 1° Cl.</td>
<td>-</td>
<td>150 km &lt; d VDT =1/7(9d/10+1125).1/6,56</td>
<td>32,3 €</td>
</tr>
<tr>
<td>Aérien</td>
<td>-</td>
<td>-</td>
<td>45,7 €</td>
</tr>
</tbody>
</table>

Recent empirical studies made by SES [Ref 61] on modal split in France, show rail modal share on main domestic routes and several short haul international routes and estimate values of time. They use a standard price-duration model using the generalised costs of modes. People arbitrate between price and time according to their values of time. They assume a log-normal distribution for values of time in the population. In this case, for each route, there is a threshold value of time corresponding to the equality of generalised costs. People with lower value of time choose rail, and people with higher value of time choose air. Using this model, they can “reconstruct” part of the distribution of the value of time, and compute the median of the distribution. They find median values close to 20 euro per hour (21.6 for domestic routes, 19.3 for international routes).

Their model show that the difference in travel time between air and rail is only one factor and cannot be the only determinant of modal split. Since half of the travelling population has a value of time inferior to 20 euro per hour, the price difference will also be a deciding factor.

However, as the travel time by train increases, it loses market shares quite fast, as can be confirmed by several studies.

In a more theoretical paper MAR GONZALES SAVIGNAT [Ref 49] studies the potential of high speed train on a link that is not yet built (Madrid Barcelona). After collecting information, he uses a probabilistic discrete choice model (logit model), in order to estimate the market share of air and rail, depending on their characteristics (travel time, access time, frequency, price) for different types of travellers. His model is more sophisticated, in the sense that it allows for values of time different for access times, waiting times and journey times (people are valuing more the time spent inside the mode).

He derives elasticities from his model, and values of time for business and leisure travellers: business travellers value time at 55 euros per hour (time spent in the mode), and access time at 22 euros. Leisure traveller have somewhat lower values, at 37 euro per hour for time inside the mode.

He draws several conclusions:

- First, the high speed train will have an important impact on the airline market, by diverting passengers.
- As travel time by train increases, the market share of the high speed train will decreases dramatically.
- For (total) travel time longer than three hours, the plane continues to be preferred to the train.
Time and time...

It is difficult to study modal split only with information on travel times (unfortunately, reliable data on travel prices are harder to find!). The modal share found by studies using only (total) travel times are therefore not very reliable, as they are highly dependant on existing (unknown) prices. A change in price with no change in travel time shall result in a different modal share.

However, it is still interesting to show how the modal split comes out nowadays, considering travel times and current prices.

We can see on the table below that there is a good statistical correlation between rail travel time and market share, for routes up to four and a half hours (routes for which air travel time is around one hour). In this graph, the Paris Brussels route is not very relevant since, there is no direct air link any more on that route.

Considering such data, we can see that with the current prices and other travel attributes (quality of service, reliability…), air and rail are on a equal footing for rail journeys of about 3 hours and a half. On the new Paris Marseille route, which is not included here, the rail has a slight advantage on the air, for a three hours journey by rail, which is consistent with this analysis.

In fact, for journeys around three hours by train, the total travel time, including all relevant access and waiting times are quite similar by air and rail, as confirm several studies.

![Curve of air/rail modal split (distance between 300 and 600 km)](image)

**Figure 8: Curve of air/rail modal split (distance between 300 and 600 km)**

Source International Union of railways (in Cokasova [Ref 12])

Several studies show that total travel time is the main feature that determines the scale of the modal shift. As a result of an equation taking into account the wasted time of travelling travelled with rail and air transport modes (180 minutes wasted time for air, and 70 minutes for rail) and the average speed of each mode (800 km/h for air, and 270 km/h for rail), COKASOVA [Ref 12] concludes that high speed rail is faster than can be used to replace airline services on journey distance not exceeding less than 750 km, or less than three hours by train.

The SES [Ref 61] considers similarly the total travel times by air, including access times, frequencies, and all relevant times (check-in…). they find that the difference in what Cokasova calls the “wasted time” between air and rail is around 100 minutes, which yields a similar result.

In addition, when applying the least square method to collected data on the rail market share on ten high speed rail links (Distance, journey time and market share of high speed rail links), we obtain that

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2 Data have been collected from several magazines
93.84% of the data variance is explained by the linear regression (Figure 9: Train market share vs. train journey time). This means that there is a strong relationship between the rail market share and the train journey time.

<table>
<thead>
<tr>
<th>High speed rail links</th>
<th>Distance (Km)</th>
<th>Train journey time (h)</th>
<th>% Train market share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paris-Brussels</td>
<td>310</td>
<td>1.36</td>
<td>94.5%</td>
</tr>
<tr>
<td>Roma-Bologna</td>
<td>358</td>
<td>2.49</td>
<td>71.2%</td>
</tr>
<tr>
<td>Paris-London</td>
<td>424</td>
<td>3.03</td>
<td>58.9%</td>
</tr>
<tr>
<td>Paris-Lyon</td>
<td>430</td>
<td>2</td>
<td>87.6%</td>
</tr>
<tr>
<td>Stockholm -Gothenburg</td>
<td>455</td>
<td>3.1</td>
<td>59.1%</td>
</tr>
<tr>
<td>Madrid-Seville</td>
<td>471</td>
<td>2.27</td>
<td>82.2%</td>
</tr>
<tr>
<td>Tokyo-Osaka</td>
<td>515</td>
<td>2.45</td>
<td>84.9%</td>
</tr>
<tr>
<td>Paris-Amsterdam</td>
<td>540</td>
<td>3.98</td>
<td>45.9%</td>
</tr>
<tr>
<td>Roma-Milan</td>
<td>560</td>
<td>4.5</td>
<td>38.4%</td>
</tr>
</tbody>
</table>

Table 3: Distance, journey time and market share of high speed rail links in 2003
Sources: WORLD BUSINESS FOR SUSTAINABLE DEVELOPMENT [Ref 72]

Conversely, the correlation between the rail market share and the rail journey distance is weak (Figure 10: Train journey distance vs. train market share) since it is only 38.9%. This result comfort the assumption that the journey time appears to be one relevant way for comparing the demand of air and rail transport modes.
To summarize, the modal split between air and rail depends mainly on travel time and prices. As journey time by train increases, the market share of the high speed train decreases dramatically. Calculations show that for 3 hours rail journey, total travel times are roughly equal by air and rail (including access, check in, waiting times...). Empirical data for modal share on existing routes show that (at current price levels) an equal market share is obtained for routes where the rail journey is around a 3.5 hours.

### 2.3.4.2 Complementarity between air and rail

Since air and rail transport modes are generally considered as competitors in the literature, their complementarity in terms of transport have been offers rarely studied. Among the studies dealing with this complementarity, COMMISSIONS DES COMMUNAUTÉS EUROPEENNES [Ref 15] explains then that HST takes advantage on aircraft on links less than 300-350 km, while aircraft takes the advantage on links exceeding 1000 km. As a consequence, air and rail transport essentially compete between 250 and 1000 km (Figure 11: Aircraft and HST markets).

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**Figure 10: Train journey distance vs. train market share**

Sources: Table 3: Distance, journey time and market share of high speed rail links in 2003
They conclude that rail/air complementarity is only conceivable on successive journeys where train operates on short sections and aircraft on long sections (in particular when air traffic is insufficient on direct link). Indeed airlines can stop operating on origin destinations when the demand is weak. The presence of an HST between a medium size city and a hub airport can allow the residents of the medium size city to have access to a large panel of destinations from the hub airport and will allow airlines to increase their load factors in particular on intercontinental links. COMMISSIONS DES COMMUNAUTES EUROPEENNES [Ref 15] estimate that in France the induced traffic by air/rail complementarity varies between 16 and 36%. In 1999 the percentage of air passengers using the TGV to reach Charles de Gaulle airport was 3.5% while this figure is expected to reach 10% in 2005.

MENERAULT and STRANSKY [Ref 51] underline that an essential condition for an effective complementarity is that a traveller arriving at CDG airport by TGV have an air connection in satisfying time conditions. They estimate that the waiting time must be comprised between 20 and 60 min.

The interconnection importance is confirmed by IATA [Ref 39] when analysing results of a customer questionnaire. When asking passengers what should be improved in air/rail intermodality, 41% answer that connection issues should be improved. Although these passengers can mean something different by “connection issues”, this high percentage translates into a real barrier to the customer (or at least some connection elements are perceived as being a barrier). According to IATA [Ref 39] some of the connection issues could include the physical layout of interchanges, the lack of integrated tickets, the time for connection, air and rail non coordinated schedules and frequencies, no assistance agreements in case of delays, etc. In particular IATA [Ref 39] observes that people without prior experience of HSR select in higher proportion connection issues than those with experience. This would mean that passengers would like information and communication to be improved.

In general, IATA [Ref 39] observes that travellers have a positive image of high speed train and that 50% of the 217 air travellers questioned by IATA have taken the high speed train before or after flying in the last 12 months. The main reason air passengers give for not using HSR before or after flying is that there are no rail service available from the airport, what tends to confirm that air passengers would be interested by air/HST intermodal transport. Once again the connection issues appear at barriers since this reason discourage 39% of respondents from using air/HST intermodal transport.

When facilitating the airport access to regional, national and European passengers, the presence of an

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Figure 11: Aircraft and HST markets
(Source COMMISSIONS DES COMMUNAUTES EUROPEENNES [Ref 15])
HSR station in airport will increase the airport catchments area. WIDMER and AXHAUSEN [Ref 71] illustrate this fact by the Figure 12:

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**Figure 12: Airport catchment area extension according to airport access time**

(source WIDMER and AXHAUSEN [Ref 71])
By improving the airport ground access, the only presence of a rail station in airports increases the catchments area. Moreover, this area is much more increased if an HSR station exists in airports.

Besides the elements presented above, distance, speed, baggage transfer, fares and passenger comfort are also crucial for travelling decisions. Nevertheless there is a lack of studies taking into account all these aspects when studying the passenger demand for air/HST intermodal transport. Studies often deal with the passenger preferences between air and HST transport modes but not on the passenger preferences between direct connection and combined transport modes. In addition, the lack of public information on figures on the passenger demand evolution for intermodal transport does not facilitate the demand analysis.

As air and rail transport compete on journey distances between 350 and 1000 km, rail/air complementarity is only conceivable on successive journeys where the train operates on short sections and the aircraft on long sections. Total journey distance and as a consequence total travel time and ticket fares are the main factors for travelling decisions. In addition an essential condition for an effective complementarity is a good level of interconnection between both transport modes.
3 Transport policy and strategic aspects

The existence and development of intermodal transports ask to have the adequate transport infrastructure allowing a good coordination and cooperation between transport modes. In the framework of the air/rail airport intermodality, it is necessary to link the railway infrastructure to the airport, i.e. to build a railway link joining the airport and a railway station at the airport.

The decision of building these intermodal infrastructures is up to States and depend on the features of their transport policies, on the project cost, on the project financing as well as the attract this project could have on transport operators and to the impacts it would have on congestion, environment, economy, etc.

In Europe, the development of the intermodality is an important objective of the European Commission. The European transport policies being able to strongly influence the national ones, we have chosen to present those concerning intermodal transports in airports in section 3.1. In agreement with these policies, several future intermodal projects at airports are planned to be developed by states. They are presented in Section 3.2. Such projects being very expensive, the problem of financing them is essential since it can put a brake in the development of intermodal infrastructures. Indeed funding from the European Commission and national governments may not be sufficient, and the possibility of private funding can have a large impact on the project realisation. Section 3.3 deals therefore with this problem by studying the financing problems these types of project can present.

If the building of intermodal infrastructure is essential for developing airport intermodality, it is not a sufficient condition. Indeed, the role of transport operators is primordial since given the available infrastructure and the traffic features, they finally take or not the decision of cooperating for proposing intermodal products. In this context, section 3.4 presents the operator strategies when studying what are the limits between competition and cooperation between transport modes.

In addition to the funding and operators’ strategies considerations States take also into account the evaluated impacts such intermodal projects could have on the society, on passengers, etc… The balance between the positive and the negative impacts of such project will finally lead States to accept or reject it. The impacts of using intermodal transports are therefore studied in section 3.5.

3.1 European policy

Intermodality and multimodality are at the heart of the 2001 European Commission white paper on transport (European Transport Policy for 2010, time to decide [Ref 25]). This white paper is the second of its kind on European transport policy. A common European transport policy is indeed a relatively new thing. It goes back to the first white paper published in December 1992, dealing mainly with the opening of transport markets.

This objective is mainly achieved today (except in the rail sector), but there remains many distortions of competition between transport modes resulting from the lack of harmonisation from a social and fiscal point of view. Some transport modes (especially road transport) are not paying their full costs (including external costs), and this distorts competition and causes congestion, which is a main problem, exerting pressure on European transport infrastructures.

Starting from this perspective, the European Commission would like to “shift the balance between transport modes”. In this context, the EC White Paper proposes several measures, some of which are directly or indirectly related to intermodality with air:

- “revitalizing the railways”
- “controlling the growth in air transport”
- “turning intermodality into reality”
3.1.1 Revitalizing the railways

In a large context of achieving a better balance between transport modes, the commission would like to increase the share of rail, control the growth in air transport, and limit the share of road transport. Intermodality is seen here in a very strong sense, as a way of limiting road or air traffic, both responsible for congestion and air pollution.

The first step is to “revitalize the railways”. Rail has lost a lot of market share and represents now only 8% of the goods transport market (21.1% in 1970) and 6% of the passengers transport market, whereas roads represents an impressive 44% (for goods) and 79% (for passengers). The EC would like to increase the rail market shares up to 15% for goods and 10% for passengers. It hopes to achieve this by several measures:

- The opening of a transeuropean rail freight market by 2008,
- A gradual opening of international passenger services,
- Removal of technical barriers (interoperability, safety)
- A better allocation of capacity (especially for freight)
- Modernisation of services
- The building of future rail links (across the Pyrenées for example)

Concerning the building of future link, the commission emphasize the difficulty of funding: transport infrastructure are costly, and the availability of public funds limited. So far, Europe could finance up to 10% of some interesting projects. The proposal is to increase this share up to 20%, in order to help to finance new infrastructure.

3.1.2 Controlling the growth in air transport

The second objective, i.e. controlling the growth in air transport, comes from the observation that airspace/ATC providers and airports have difficulties coping with the constant increase of air traffic. Intermodality is seen as one solution (among others) to this problem: Since airports have a limited capacity, the commission considers that whenever possible, air services should be transformed into rail services, thus freeing capacity for other air routes.

“Intermodality with rail must 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 service exists.”

We can see that the development of intermodal agreements between air and rail operators (next section) are only a first step for the European commission, and they assume that intermodality will and should result in replacement of air services by rail services, which does not seem obvious, considering the present state (very few air routes closed down so far when intermodal agreements are signed). The operators’ strategies will be developed in section 3.4.

3.1.3 Turning intermodality into reality

The third objective “turning intermodality into reality”, aims at improving modal transfers for passengers. These transfers are still problematic and put many passengers off using different modes on a journey. This should be done by integrated ticketing (and service), baggage handling, continuity of
journeys (good interchanges, and connections), good quality of service.

### 3.1.4 Adopting a policy in effective charging for transport

The fourth objective “adopting a policy in effective charging for transport” aims by a “fair” charging policy, at putting all modes on a “fair” competitive setting. This amounts to charging differently for the use of roads, because so far, external costs (congestion and pollution) are not taken into account in road charges. Infrastructure costs are not recovered either, on most routes (except toll roads). Such a policy would clearly be advantageous for the railways in terms of congestion and pollution costs, but it is not so clear-cut if you look at infrastructure costs. Changing the charging policy, however, could prove difficult because most modes already have a pricing system, conceived for each mode and each country.

To summarize, we can see that the European commission is largely favourable to the development of intermodality, especially with the railways. Nevertheless, it has limited means of action, and may also have a view that does not appear to be supported by evidence of air/rail complementarity and competition.

### 3.2 Future air/rail intermodal projects

When being waiting areas, correspondence and passage points from a state to another, airports become what were railway stations at the 19th century. However, due to physical and nuisance constraints they often have to move away from city centres what increases their access time. In addition airport access remains reliant on vicissitudes such as road congestion and meteorological hazards. Governments being responsible among others of infrastructure planning by taking into account environmental impacts, they plan to encourage the airport access by public transport. As the rail being is considered as the most ecologic transport mode and the less sensitive to meteorological constraints, many States plan to develop the airport access by rail links.

#### 3.2.1 Future airport access

The choice between different categories of airport links will depend on numerous criteria such as geography, the likely scale and the nature of the demand and the funding available [Ref 38]. IARO, ATAG, ACI [Ref 38] provide a table giving some indications of current best practice.

<table>
<thead>
<tr>
<th>Team</th>
<th>Light rail</th>
<th>Metro Railway</th>
<th>Suburban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passengers/ hour (000)</td>
<td>2 - 5</td>
<td>5 - 20</td>
<td>15 - 30</td>
</tr>
<tr>
<td>Right of way</td>
<td>Shared or dedicated</td>
<td>Largely dedicated</td>
<td>Dedicated</td>
</tr>
<tr>
<td>Station spacing (metres)</td>
<td>500 - 1000</td>
<td>750 - 1500</td>
<td>1000 - 2000</td>
</tr>
<tr>
<td>Signalling</td>
<td>On sight</td>
<td>Train protection</td>
<td>Automated block</td>
</tr>
</tbody>
</table>

Table 4: indications of current best practices for airport rail system
Observation of Table 4 shows that the number of air passengers is essential when deciding of the type of airport rail links. Indeed if the number of passenger per hour is less than 5,000, the tramway link seems to be the most appropriated railway. When exceeding 5,000 passengers an hour, Express trains (what IARO, ATAG, ACI [Ref 38] names the light rail) are generally preferred. Nevertheless the boundaries between express trains, metro and suburban railways are not so clear. It would seem that the choices between metro and suburban stations will not only be linked to the number of passengers but also with the possible station spacing. The more the distance between stations is needed to be short, the more the suburban railway will be chosen.

The following projects are among the different European countries planning to implement airport access by rail links:

**Copenhagen metro**: In October 2002, the Danish capital, København, got its first metro line running fully automated from east to west. The next phase of the metro project is the so-called Østamagerbanen, the link between Lerrgvsparken and the Copenhagen airport which is planned for 2007. The trip from Kongens Nytorv to Lufthavnen (Copenhagen Airport) will take 13 minutes. Funding for the Metro has come from loans to be paid back over 25-30 years from operational revenue, sale of land in Ørestad and through contributions from Frederiksberg City Council and Copenhagen City Council.

**CDG Express**: Paris-Roissy is one of the most loaded sectors of the French transport network. With 48.3 millions of passengers in 2002 Roissy CDG is the 7\(^{th}\) airport in the world and the second in Europe. Despite the airport rail connection with the TGV and the RER, 81\% of passengers access the airport by car. In addition Roissy is the most important activity zone in Ile de France with more than 70,000 employees. While both runways allowing to access the airport are the most congested of Ile de France, the use of RER discourage passengers due to its complexity and its inadequacy to the need for luggage transport. As a consequence of the air proportion of air travellers (more than 50\%) going to Paris centre from CDG, travellers whish improvements of the airport access by rail transport. When planning to link CDG to Paris centre (Gare de l’Est) in 15 minutes 4 times per hour, CDG Express aims at answering these wishes.
CDG Express will use the existing rail network between Paris and Noisy le Grand and will necessitate to create a new infrastructure between Noisy le sec et Tremblay en France. In order to preserve the environment and to prevent from expropriations, this infrastructure will be constituted by a tunnel. The tunnel construction is planned to start in 2006 and the CDG Express is expected to be launched in 2012.

The CDG Express will be financed at equal parts by Aéroport de Paris (ADP), Reseau Ferré de France (RFF) et Société National des Chemins de Fer (SNCF).

**Porto light rail system:** During this year Porto Airport, managed by ANA, will be integrated in the new Porto Light Rail system, that will integrate the Airport in the city and regional transport network, and ensure the connection with the conventional rail network.

### 3.2.2 Future airport link with high speed railways

CCFE-CER-GEB, UIC, UNIFE [Ref 10] estimates that an appropriate policy could reinforce the complementarity in terms of transport offer between air and rail many thanks to the high speed rail links allowing to transport passengers from and to large metropolis. Indeed PLANCO CONSULTING Gmbh [Ref 56] shows that neither community, nor regional or national airports place emphasis on intermodality. Among the 63 international airports considered by PLANCO CONSULTING Gmbh [Ref 56], only 30% provide intermodal facilities. According to Figure 15: Development of intermodal capabilities of contacted airports a significant change in this situation is not expected for the next 10 years. Nevertheless PLANCO CONSULTING Gmbh [Ref 56] underlined that long-term strategies are in many cases not provided.
If at the current time three European airports (Paris CDG, Lyon and Frankfurt) are connected to the high speed network, six other airports are planned to implement this connection (Paris Orly, Milano Malpensa, Stuttgart, Köln, Amsterdam and København) (Figure 16).

By 2010, it is expected that frequent direct Thalys International services will be linking Paris CDG, Brussels National and Amsterdam (Schipol) airports in replacement for the present air services between them (which is a high speed line between Paris CDG and Brussels station, but not with Amsterdam airport).

By 2020, the Portuguese transport ministry plans to build four connections to Spain and a connection...
between Lisbon and Porto. This project is expected to allow the rail market share to increase from the present 4% to 26% by 2025. The connections between Portugal and Spain were agreed in Figueira da Foz Summit (November 2003). There will be 4 rail lines connection between the two countries by 2020 (Figure 17: Portuguese Rail Network Plan – Iberic connections). Only the Lisbon-Madrid line will allow speeds up to 350 Km/h.

![Figure 17: Portuguese Rail Network Plan – Iberic connections](image)

Among these four new rail links two of them are planned to be connected to airports:

- the Oporto-Vigo link will connect oporto International airport. Three years (2006/2009) will be necessary for the building of this link which will cost 1.3 million Euros. The link will connect oporto to Vigo in 40 minutes with an average speed of 200-250 km/h and is expected to carry 2.1 million of passengers.

- the Lisbon-Oporto link will connect Lisbon and Porto International airports. Seven years (2006/2013) will be necessary for the building of this link which will cost 4.2 million Euros. The link will connect Lisbon to Oporto in 40 minutes with an average speed of 300-350 km/h and is expected to carry 5.3 million of passengers.

Unfortunately there are not many information on the other projects shown on Figure 16: Airports linked to the high speed network and we are therefore not able to provide more details on them.

### 3.3 Financing air/rail intermodal projects

When associating the extension of the high speed network with a global transport policy, European countries expect to reduce the air traffic congestion by freeing airport and ATM slots. In order to achieve this result some European countries plan to improve connections between rail and air transport modes by building railway stations inside airport terminals. Nevertheless building railways supposes
large investments in railway infrastructure which can sometimes put a brake in the development of intermodal infrastructures. Indeed funding from the European Commission and national governments may not be sufficient, and the possibility of private funding can have a large impact on the project realisation.

### 3.3.1 Costs

In general the intermodality between air and rail exists because the railway network is extended to the airport area but not because the airport has been located on an existing railway network. As a consequence the cost for developing air-rail intermodal infrastructures is mainly linked to railway investments. For instance, the cost of the Express airport line in Oslo-Gardemoen airport was $11.3 millions. Added to the cost of building railways, infrastructure costs are also composed of the cost of building the railway station in the airport terminal.

Unfortunately detailed information on the cost of building different categories of airport railways are not available. In particular details on the cost of express trains are not published. Nevertheless studies examining the cost of high speed rail network exist and can be used for having a better knowledge of the infrastructure costs of such transport modes.

In particular, LEVINSON D., MATHIEU J.MM, GILLENE D., KANAFARI A. [Ref 44] provides the infrastructure costs of French TGV (Table 5).

<table>
<thead>
<tr>
<th>Route</th>
<th>Distance (km)</th>
<th>Cost (US $)</th>
<th>Cost per km (US $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South-East</td>
<td>1004</td>
<td>$ 2,058,000,000</td>
<td>$ 2,049,000</td>
</tr>
<tr>
<td>Atlantic</td>
<td>726</td>
<td>$ 1,724,000,000</td>
<td>$ 2,375,000</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>800</td>
<td>$ 4,047,000,000</td>
<td>$ 5,058,000</td>
</tr>
<tr>
<td>East</td>
<td>1080</td>
<td>$ 4,371,000,000</td>
<td>$ 4,047,000</td>
</tr>
<tr>
<td>Total</td>
<td>3610</td>
<td>$ 12,200,000,000</td>
<td>$ 3,380,000</td>
</tr>
</tbody>
</table>

**Table 5: French TGV infrastructure cost**
(Source LEVINSON D., MATHIEU J.MM, GILLENE D., KANAFARI A. [Ref 44])

Cost per kilometre of the French TGV varies from 2.05 to 5.06 million dollars. The higher unit cost of Mediterranean and East TGV is due to their more urbanized or mountainous areas. Indeed if the area is very urbanised, the railway construction will need to expropriate numerous persons and give them financial compensation. In addition the construction will have to protect neighbours from rail nuisances (especially due to noise). If the area is mountainous, construction cost could be increased due to its complexity (for instance construction of tunnel).

When comparing the infrastructure costs of different transport system in California, LEVINSON D., MATHIEU J.MM, GILLENE D., KANAFARI A. [Ref 44] find that the cost per passenger kilometre of high speed rail is 7 times higher than the cost for air system and nearly 11 times higher than the cost of highways. As a consequence we can wonder who pay for the new air rail links?

### 3.3.2 Public funding

Bus services to airports might be preferred to rail services due to their advantage of flexibility and low infrastructure costs. The choice between rail and bus access to airport is currently the subject of a debate in the United-States, where the share of public transports to airport is quite low (only 15% compared to the 35% in the four main European airports) and the congestion on access roads is
severe. Unfortunately we do not have much information on airport bus funding and we will concentrate this section on the funding of railway.

In its White Paper, the EUROPEAN COMMISSION [Ref 25] underlines that the financing of rail infrastructure is a major concern in the European Union. Rail infrastructure is costly and finding funds in order to finance rail access to airports may not be an easy task. Following a European directive of 1991\(^3\), railway operators are separated from rail infrastructure managers. According to this directive the infrastructure manager is “any public body or undertaking responsible in particular for establishing and maintaining railway infrastructure, as well as for operating the control and safety systems”.

If part of funding can be public, public funds coming from the European Commission and/or the National governments are limited and private funding can be a favoured alternative or complement.

**European funding**: The share of a project cost financed by the European Commission can not exceed 20%. When trying to resolve at least partly the financing problems relative to the high infrastructure costs of railways, the EUROPEAN COMMISSION [Ref 25] proposes to enable cross subsidies inside a region. A new rail links having consequences on other traffics, revenues from other infrastructures in a region (mainly toll road) could be used partly to help financing rail infrastructure. Nevertheless the EUROPEAN COMMISSION [Ref 25] does not clearly explicit how this scheme could be applied to airport rail access.

**Government funding**: Historically, the usual form of funding for rail infrastructure in many countries has been central, regional or local authority when applying the normal funding mechanism for transport infrastructure. Nevertheless the three authorities have a limited budget and they not always have the airport rail links on their priority list.

The initial costs of building railways being high, and railway and airport operators can dread bearing all investments and governments often have to provide funding for the effective realisation of this project. GRUYER N., LENOIR N [Ref 37] explain that although access charges would allow to get airport links financed it could limit the possibilities. Only profitable links can be built by this way, and the infrastructure managers may be forced to grant exclusive (time-limited) franchise rights to the railway operator, resulting in prices that are higher than the socially optimal prices”. At the same time, authorities could have to allow exclusive agreement between air and railway operators. Without this exclusive agreement, airline operator could dread loosing its advantage on the intermodal links if other airlines could conclude an agreement with the railway operators and could dread the project to be unprofitable. This exclusive agreement could allow to guaranty that operators would be interested in this project and would be in favour of the infrastructure building.

| To summarize, allowing exclusive agreements between air and rail operators could allow to guaranty that operators would be interested in this project and would be in favour of the infrastructure building. |

| 3.3.3 Private funding |

The existence of private funding for rail airport access will depend on the profitability of the project according to the investors. In general only air or rail airport business would be interested in investing in the project due to the long term aspect. Investment may be recovered after 20-25 years.

As a consequence only air and rail operators could be interested in financing a part of the rail infrastructure, depending on the profit they expect to derive from the use of the infrastructure.

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Airport funding: although they can expect an increase in their number of passengers, airports can fear to obtain fewer revenues from parking lots if a direct rail link exists to the city centre. Indeed, parking spaces are an important source of revenues and airports do not have strong incentives to finance rail links, unless road access becomes problematic. This lack of incentives is less clear for connections between the airport and the national rail network (in particular the high-speed network). Once being connected to the national network, airports increase their catchments area and become more attractive for regional travellers what may result into more traffic for the airport.

Airline funding: When interviewing several airlines representatives IATA [Ref 39] finds out that they see air/rail intermodality favourably. The estimate that this may increase their catchment area and give them an edge on competitors if they have an exclusive agreement. Nevertheless their expectations of intermodality are not high and they are also uncertain about the relations with the rail operators (which will become partners on some routes and competitors on others). As a consequence airline operators are generally not willing to invest in airport rail infrastructure. Some of them have partly solved the access problem by proposing bus links to the city centre (for instance Air France in Paris). If there is one rail operator, and if the dominant airline has the legal possibility of conclude an exclusive agreement with the rail operator, GRUYER N., LENOIR N [Ref 37] explain that the possibility of co-financing the rail infrastructure can be more desirable for airlines since their relationship will be on the long term.

Railway operators funding: Since railway operator can expect deriving profits from operating the services and has private information about cost, demand and profitability of new links, it is one of the most appropriate candidates for participating to the financing of rail infrastructure. In Europe even if this should change at least on international links\(^4\), railway operators are used to operating on monopoly conditions. If it is (legally) possible to sign exclusive intermodal agreements, which can in some cases lead the airline to abandon certain routes, leaving the rail alone on those routes, then the infrastructure become all the more interesting for the rail way operator.

Rail infrastructure manager: One other appropriate candidate for financing rail infrastructure is the rail infrastructure manager which could derive funding from access charges. CAILLAUD B., TIROLE J. [Ref 8], in a setting of information asymmetry between the infrastructure manager and an incumbent (railway) operator, show that the infrastructure manager (subject to a budget constraint), deriving funding from access charges and funding contributions may have to limit access in order to get project built. Since competition lowers profit, an open access policy to the infrastructure would be better from a social welfare point of view. Nevertheless it may result in a situation where the access charges are too low (considering what the operators are willing to pay) to ensure the viability of the project. Under perfect information, the infrastructure manager will have an open access policy if demand is high, since profits in a competitive situation (duopoly) will enable the manager to charge access fees sufficient to balance its budget. If demand is low, the project will not be built. In intermediate situation, manager will grant an exclusive franchise right to the incumbent, rather than facing the risk of the project not being built. In this case it is possible to design a mechanism to reveal the incumbent’s information. CAILLAUD B., TIROLE J. [Ref 8] suggest that in some cases, it is possible to improve upon the exclusive franchise policy, by setting a time limited exclusive franchise, followed by an open access policy. One application of this principle is the Arlanda Express link to Stockholm city centre, where the consortium A-Train financing the infrastructure got an exclusive operating franchise, for a duration of 40 years. Until 2040 the consortium A-Train will operate and receive all revenues from fares. CAILLAUD B., TIROLE J. [Ref 8] also suggest that when it is difficult to elicit information from the incumbent, the infrastructure manager has to get as much information as it can get on its own about demand for the new infrastructure. As a consequence CAILLAUD

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\(^4\) The European Commission has adopted a third railway package (3rd March 2004) proposing the opening up of the market for international passenger services in 2010.
B., TIROLE J. [Ref 8] show the important role of the incumbent operator which can orient somehow the choice infrastructure being built, because of the asymmetry of information. In addition the manager aiming to maximise its profit, it may prefer to link airports to their national network than linking airport to city centre even if this last link would maximise the social welfare. When linking the airport the national rail network (mainly to high-speed rail network), the manager would exploit complementarity with airlines rather than facing direct competition. This notion of complementarity was not obvious in the 70’s, when the French high speed network was designed and Roissy airport linked to the national network. This attitude has changed when rail and air operators realised that they both could benefit from this complementarity by cooperating. This cooperation is essential since GRUYER N., LENOIR N [Ref 37] show, that one determinant element of the profitability of the future link is the possibility of signing intermodal agreements. This may be the key element when deciding whether it should be built or not.

As a consequence funding of airport rail access can result in complex funding such as in Paris Charles de Gaulle as well as in Zürich airport. Different organisations own different layers of the airport station (posing inevitable interface issues).

To summarize, even if airports can fear to obtain less revenues from parking lots if a direct rail link exists to the city centre, they can be incited to finance connections with the rail national network when they can expect to increase their catchment area. Although rail infrastructure manager and railway operators are the most appropriate candidates for financing rail infrastructure, the possibility of co-financing the rail infrastructure can be made more desirable for airlines if an exclusive agreement is signed with the railway operator.

3.4 Operators’ strategies

One important factor leading transport operators to cooperate for providing intermodal services is the possibility to get financial profits. In particular we can assume that the air-rail intermodality will attract more passengers on the rail segment what should allow railway companies to increase their profits (subject to an appropriate pricing policy). Incentive to cooperate is certainly less evident for airlines. These ones have incentives to cooperate only if they estimate not bearing losses. For existing intermodal links, airlines incentive was often because the rail segment was short (less than 2 hours) and the market share of rail on this route was already large. This was the case of Air France on the Paris-Brussels route. The air-rail coordination has allowed Air France to avoid totally loosing the market on this line.

One other important factor taken into account in the decision of providing intermodal transport is to be sure that the cooperation will not results in large operating costs leading to financial losses.

That is why the conditions of the agreements are essential and the airline incentive could vary according to the fact that this agreement is or not exclusive.

3.4.1 Financial aspects of intermodality

GIVONI [Ref 32] provides a comparison of the operating cost estimates of HST and aircraft between London Heathrow airport and Paris centre.
Table 6: Comparison of HST and flight operating costs on the London Heathrow airport to Paris route (Euro)
(Source GIVONI [Ref 32])

<table>
<thead>
<tr>
<th></th>
<th>HST route costs</th>
<th>B737-300 route costs (direct)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Direct</td>
</tr>
<tr>
<td>Total operating costs</td>
<td>37,200</td>
<td>22,900</td>
</tr>
<tr>
<td>Operating costs per seat</td>
<td>49.6</td>
<td>30.5</td>
</tr>
<tr>
<td>Operating costs per seat-km</td>
<td>0.094</td>
<td>0.058</td>
</tr>
<tr>
<td>Operating costs per passenger</td>
<td>104</td>
<td>64</td>
</tr>
</tbody>
</table>

¹ Assuming 30% increase in landing charges due to emission charges.
² Assuming the high estimate for cost of climate change.

In Table 6, the HST direct operating cost is differentiated from the total operating cost. At the same time, GIVONI [Ref 32] proposes 4 costs values for aircraft (B737-300) operating cost. He differentiates the base cost from the peak time cost because London Heathrow airport imposes higher charges at peak periods for reducing the congestion. A third value represents the operating cost at peak period when an increase of 30% in landing charges is assumed because of the environmental costs imposed on society. The last cost represents the operating cost at peak period when taking into account the cost of climate change.

The comparison of the total operating costs by modes in Table 6 shows that even when taking into account additional charges relative to the peak periods and the environmental costs, aircraft operating costs are significantly lower than rail costs. Nevertheless this result is less obvious when comparing unit costs. Indeed although the total HST operating cost is always higher than the aircraft operating cost, this is not always the case when only comparing with the direct HST cost. Since it is assumed that the airline will have to bear only the direct HST costs the comparison should only be made with this cost. In this case the cost advantage of the aircraft is less clear.

Comparing the operating cost by mode in terms of seat-km shows the advantage of the HST but in terms of operating costs per passenger the advantage shifts to aircraft. This last result can be explained by the low load factor assumed for HST. Indeed GIVONI [Ref 32] assumes that the HST load factor is 48% against 70% for the aircraft.

Nevertheless this analysis compares two modes assuming that they operate on the same route but it is not totally true since the flight lands at CDG airport while the HST arrives at Paris city centre. The cost of travel from CDG airport to Paris city centre could then be added to the cost of flight, despite this cost is not borne by the airline. GIVONI [Ref 32] estimates that the additional cost would be 120 Euros or under 1Euro per seat. Including this cost as part of the airline operating costs when operating aircraft services reduces the cost difference between the modes and makes the HST a better option if considering the environmental charges.

As a consequence the fact that operating services of air transport is less costly than for high speed rail transport is not only related to the fact that the HST has a greater route distance but also that the airline has not to bear the cost of bringing the passenger to the city centre. Therefore, replacing the aircraft
services with HST services should depend, in terms of operating costs to a large extent on the route circumstances and the HST route distance in comparison to flight distance. This leads GIVONI [Ref 32] to conclude that shifting their operation to HST services will not necessarily result in operating cost savings and could incur losses.

Nevertheless GIVONI [Ref 32] has only focused on the LHR-Paris route on which the rail journey time exceeds 2 hours. It is generally considered that the air-rail intermodality can only exist if the rail journey does not exceed 2 hours. Below this limit the train can be considered as a feeder for the airport. The cost comparison should then concern other routes (as for instance CDG airport-Lille).

### 3.4.2 Possible form of an agreement

The degree of intermodality between different transport modes depends on the type of agreements chosen by transport operators. Agreement has first of all to concern the operators’ timetable coordination in order to minimise connection time. When analysing the case of the existence of a railway station in an airport where is located a dominant hub airline, GRUYER N., LENOIR N [Ref 37] consider that railway operators can always be incited to coordinate their timetables to those of the dominant airline (independently to the existence of an agreement) in order to attract air passengers. If airlines can be less interested in this coordination without agreement with railway operators, GRUYER N., LENOIR N [Ref 37] show that « the frequency of the railway operator’s trains generates positive externality for the airlines”. Indeed, the dominant position of the airline on the airport may be reinforced by the coordination of the train frequencies with its timetables.

Nevertheless coordinating the operators’ timetable is not sufficient for forming an efficient intermodal agreement. Indeed, the pricing coordination has also to be taken into account. GRUYER N., LENOIR N [Ref 37] suggest to extend the yield management system to the entire journey what would result in selling air and train ticket together. Applying a common pricing is very important since it would allow avoiding “the double marginalisation phenomenon”. GRUYER N., LENOIR N [Ref 37] show that if prices are not coordinated, not only the total journey (train + aircraft) will be more costly for the passenger, but the profit of both operators considered together will be lower. Indeed, the railway operator will not be able to discriminate between passengers travelling on the entire journey and the others. A coordinated pricing should then dissuade high paying passengers from choosing the economy fare by degrading the related provided service. The price discrimination should then concern the level of comfort, the possibility of checking luggage at the departure railway station, the possibility of taking another flight in the case of delayed train (or on the contrary to take another train in case of delayed flight), etc. The pricing discrimination already used by airlines would be applied to the entire journey what means that there would be no need to apply a specific differentiated pricing to the rail journey.

However, this common pricing would require to have a perfect information transmission between operators which is generally not the case. In general information asymmetry between operators may not facilitate the elaboration of an agreement. The possibility of concluding an exclusive agreement could be an important factor influencing the rail/air cooperation. Indeed airlines would be more ready to conclude an intermodal agreement with a railway company if it is certain that its rivals will not be able to negotiate other agreements. As a consequence an airline would be less tempted to conclude intermodal agreements if there are several railway operators. In this case the airline will not be able to prevent its rivals from negotiating routing agreements with other railway operators. At the same time, the railway company would be interested in concluding an exclusive agreement if the airline stops operating or reduce its frequencies on the considered route.
A company will be interested in concluding an exclusive agreement if the airline stops operating or reduces its frequencies on the considered route.

### 3.4.3 Limit between competition and cooperation

Historically, airlines and railway companies have operated as competitors but the interconnection of their network thanks to the existence of railway station at airport terminal has lead them to cooperate on certain route. Railway companies and airlines can then be complementary in the market for connecting passengers on hub airport and at the same time rivals in the market of point-to-point travel. In this situation it is not easy to determine where the limit between competition and cooperation for both transport modes is. When studying the mechanisms allowing to limit competition between airline and railway operators GRUYER N., LENOIR N [Ref 37] show that there is, under certain conditions, a Nash equilibrium for which the operators do not compete anymore each others. This Nash equilibrium means that neither railway company or airline will be tempted to change its fares in order to take over its rival’s market.

The GRUYER N., LENOIR N [Ref 37]’s model assumes that travellers with a high value of time are a natural market for airlines while travellers with low value of time are a natural market for railway companies. When assuming that both operators simultaneously set their profit margins GRUYER N., LENOIR N [Ref 37] explain that if the railway company sets a very high fare and the airline a very low fare all passengers will choose travelling by plane, while if the airline sets a very high fare and the railway company a very low fare all passengers will choose travelling by train. A third case happens when airline and railway companies choose fares so that high paying travellers choose plane while low paying travelling travellers choose train. GRUYER N., LENOIR N [Ref 37] shows that the Nash equilibrium can be obtained in this third zone. In this particular case, both operators charge their monopoly price on their natural markets and have no interest in competing. However the existence of this equilibrium is highly correlated with the journey time by plane compared to the journey time by train. The shorter is this journey time, the more likely is the Nash equilibrium. Indeed if this journey time decreases, the airline monopoly price increases according to the added value of the flight for the time-sensitive passengers. In order to attract these time-sensitive passengers the railway company would have to largely decrease its fare and would find less interesting to capture this passenger category. As a consequence the existence of the Nash equilibrium will largely depend on the fact that airline and railway company products are “differentiated substitutes”. In this case, the railway operator can find an interest in improving the quality of the airline’s product by better interconnecting networks for example.

### 3.5 Impacts

When promoting air/rail intermodality, the EUROPEAN COMMISSION [Ref 25] expects resolving, at least partly, some of the current negative effects of transport. By substituting on some particular routes rail for air transport, the EUROPEAN COMMISSION [Ref 25] expects not only to reduce airport congestion by freeing airport slots, but also to decrease environmental nuisance. In addition, by improving the airport accessibility intermodality is also expected to provide beneficial impacts on the economy (mainly on the regional economy). Although the impacts on the environment, congestion and economy appear to be obvious in the literature, a small number of articles try to quantify them.

Besides the operational constraints related to the cooperation between different transport modes, airport intermodality sets security problems as for instance the transfer of luggage. Unfortunately, no study on the impacts on security problems is available at the present time preventing us from presenting them in this section. At the same time, such intermodality could impact on safety levels since the passenger safety has to be insured during the whole transport, including the transfer between
modes.
If the possibility to use intermodal transport to air can influence passenger’s preferences in terms of transport, this will also impact on its welfare. Despite the fact that studies dealing with this type of impact are not available at the current time, it is however possible to stress how this impact could be evaluated.

### 3.5.1 Impact on congestion

When analysing the forecasted trend of air transport demand in Europe IATA [Ref 39] concludes that the current congestion situation of the main hub could increase in the next 6 years. Many hubs would be congested by 2005 meaning that a substantial proportion of airlines requesting slots would not be satisfied. As stressed by IATA [Ref 39], the percentage of unsatisfied demand for slots would vary from 6 to 26% among the 9 main European airports in 2005 and would reach 13 to 40% in 2010.

![Figure 18: Percentage of demand not met in 2000, 2005, 2010 (source IATA [Ref 39])]
Moreover illustrations of airlines having stopped to operate on routes because of the presence of rail links are scarce. The Paris CDG-Brussels links seems to be the only case to date. It seems that the weakness of Sabena has played a major role in the Air France decision of stopping its flights on this route. Indeed, Air France did not dread Sabena competition and realised that its benefit would be higher by cooperating than by competing with the Thalys. On the other routes airlines continue flying on route where there is rail competition in order to keep the control of their network offering.

In addition airlines refute the argument that they lose money on short-haul flights. Indeed, over the last few years major airlines have transferred short-haul routes to regional airlines. These being more cost effective they generally manage to operate profitable short-haul flights on the behalf of major airlines.

IATA [Ref 39] concludes then that according to evidence and views they have collected “the impact of high-speed rail connections will free up a limited number of slots at key airports”.

The IATA [Ref 39] study only takes into account the opinion of passengers and air operators but there is a lack in the literature on studies estimating the real impact of air/rail intermodality on airport congestion.

**3.5.2 Impact on the environment**

The main environmental impacts of air transport can be divided in three groups:
- noise
- local air pollution
- climate change (or greenhouse effect)
When presenting the difference between local pollution and climate change GIVONI [Ref 34] differentiates parts of the atmosphere: ground level, the troposphere (lower atmosphere) and the stratosphere (upper atmosphere). The local pollution concern the gas emission produced on the ground level while the climate change is relative to emissions produced in the entire sky.

![Diagram of the atmosphere layers and aircraft's flight and cruise altitude](Source GIVONI [Ref 34])

Airlines being high consumers of energy, if they eliminate 10 daily flights IATA [Ref 39] estimates that this would eliminate the rejection in the air of 6 700 tons of CO₂.

The main environmental pollutants presented by GIVONI [Ref 34] are summarised in Table 7:
Nitrogen Oxides (NOx):
NOx affect human mortality and morbidity through three separate channels: as NO2 directly, as ammonium nitrate (a component of PM10) and through a secondary reaction with VOCs resulting in the formation of Ozone, which affect climate change. NOx affect lung function, and may harm immune system cells, increase susceptibility to infection and aggravate asthma.

Sulphur Oxide (SOx):
SO2 can affect human health through two main channels, directly as SO2 concentrations and through its oxidation in the atmosphere to form small particulate matter (PM). Emissions of this colourless, although strong smelling, gas can result in bronchitis and other diseases of the respiratory system. Coal fired electricity generation is a major source of this gas as well as diesel fuel.

Particulate Matter (PM10):
Often referred to as small particulate matter these are solid and liquid particles in the air of under 10-micron diameter. Evidence exist that link PM10 and premature mortality and morbidity. Particulates are associated with a wide range of respiratory symptoms including coughs, colds, phlegm, sinusitis, shortness of breath and more. In some of the studies discussed in this paper the term aerosols (or Aer.) is used and this will be considered as PM for the analysis.

Carbon Monoxide (CO):
CO can have detrimental effects on health because it interferes with the absorption of Oxygen by red blood cells. This may lead to increased morbidity. CO is especially a problem in urban areas where synergistic effects with other pollutants means it contributes to photochemical smog and surface Ozone (O3). CO emissions result from incomplete combustion and some 90% of all CO emissions originate from the transport sector.

Hydrocarbon (HC):
HC is an organic compound that contains the elements of carbon and hydrogen only. Benzene, the simplest member of the class is a known carcinogen, causing leukaemia.

Volatile Organic Compounds (VOC):
These comprise a wide variety of hydrocarbons and other substances. They generally result from incomplete combustion of fossil fuel. Besides respiratory problems some of the compounds are suspected of being carcinogenic.

Table 7: Main environmental pollutants
(source GIVONI [Ref 34])

While HC, CO, NOx, SO2 and PM10 are relevant for analysing the air pollution, CO2 and NOx are used for studying the impact on climate change.

When studying air pollution impact of air and HST travel on the London-Paris route, GIVONI [Ref 34] decomposes the comparison in three steps. The first step compares the two option journey in terms of emission per seat supplied on route. But because of the different aspects each gas has on air pollution and climate change, it has no sense to sum the gas emissions. That is why the second step considers the impact of each gas by taking into account the toxicity factor of the gases for the air pollution and by using the unit of CO2 equivalent for the climate change. The third step evaluates the cost of the damage caused by emission occurring during the journey.

The first step of the analysis leads GIVONI [Ref 34] to conclude that the journey by air results in more emissions in HC, CO and NOx while the journey by HST results in more emission of SO2 and PM10. As these gases have different impacts on air pollution it is impossible to determine which mode is preferable. At the same time analysis of gas emissions impacting on the climate change show that the journey by air leads to substantially more emissions of CO2 and NOx.

When evaluating the impact of each gas in the second step of the analysis, GIVONI [Ref 34] observes that HST is always a better option in terms of impact on air pollution and climate change (Table 8). This result is less evident when taking into account the social cost (which is the cost for the whole society) of the emissions. Indeed, while the social cost of air pollution seems to be higher for an HST journey, the social cost of the climate change is lower for this transport mode.
Table 8: Comparison of environmental impacts of aircraft and HST journeys

This analysis shows clearly that evaluating the environmental impact of each mode is not obvious since results can vary according to the chosen unit of comparison. Nevertheless the cost comparison has to be taken with consideration. Indeed, taking other social cost values per unit of gas emission would certainly lead to different results. This is illustrated by GIVONI [Ref 34] when applying to different social cost unit for the emission affecting the climate changes. In 2001 21 815 flights were recorded between LHR and CDG airports (CODA, 2002). If all the flights were served by B737 (128 seats) a total of over 2.79 million seats were offered on the route. Providing 2.79 million seats between London and Paris with HST instead of aircraft would result in an increase in air pollution of 3.5 million Euro. On the other hand this would also result in a decrease in damage from climate change of 1.8 million Euro if using the low cost estimate, and 11.5 million Euro if using the high cost estimate for climate change. Givoni comments that if the cost of damage in terms for climate change is assumed to be low, air journey has to be preferred to rail journey, while the opposite conclusion is made if the cost is assumed to be high (Table 9). As a consequence GIVONI [Ref 34] advises to prefer adopting the second level of analysis.

Table 9: Environmental cost/benefit from shifting aircraft services between London and Paris to the HST in 2001 (Million Euro)
(Source GIVONI [Ref 34])

This difference in unit cost is underlined by EUROCONTROL [Ref 23] which compares the cost of air pollution per passenger estimated in the literature.

Table 10: Costs of air pollution by transport mode: US cent per passenger or tonne kilometre
The observation of Table 10 shows that although the estimation of air pollution cost varies considerably between studies, the rail is always considered as less air pollutant. EUROCONTROL [Ref 23] illustrates this result of studies providing the external costs of air, road and rail transport on specific corridors (Table 11).

Table 11: External cost of road, rail and air transport per trip (EURO per 1000 Km)

(Source EUROCONTROL [Ref 23])

Comparison of external cost on the Frankfurt-Milan route, shows that as well for air pollution than for climate change (global warming) the rail transport has less disastrous effects than the air transport what is at odds with the GIVONI [Ref 34] results. As a consequence the conclusion of GIVONI [Ref 34] explaining that shifting services from plane to train will not automatically result in environmental benefits is not always shared by other authors having also studied the problem.

To summarize, authors disagree when quantifying the environmental impact of air/rail intermodality not only due to the difficulty of measuring the air pollution but also of evaluating the social cost per pollution unit.

3.5.3 Impact on the economy

By facilitating the accessibility of the European regions, airports play an important role for the integration of the remote areas. The presence of an airport participates to the compartmentalization of regions by favouring the tourism development, the employment creation, the financing of vital services such as hospitals, colleges, universities, etc.

ACI [Ref 2] considers that the overall economic impact of airports is:

- **direct**: employment and income wholly or largely related to the operation of an airport
- **indirect**: employment and income generated in the economy of the area in the chain of suppliers of goods and services
- **induced**: employment and income generated in the economy of the area by the spending of incomes by the direct and indirect employees
- **catalytic**: employment and income generated in the economy of the area by the wider role of the airport in improving the productivity of business and in attracting economic activities, such as inward investment and inbound tourism

When analysing the contributions of airport activities on the European GDP level, ACARE [Ref 1]...
concludes that in 2000 0.39% of the GDP was related to airport activities.

<table>
<thead>
<tr>
<th>Airports</th>
<th>Direct effect</th>
<th>Indirect effect</th>
<th>Induced effect</th>
<th>Total impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution to GDP in percentage</td>
<td>0.12%</td>
<td>0.14%</td>
<td>0.13%</td>
<td>0.39%</td>
</tr>
</tbody>
</table>

**Table 12: Impacts of airport activities on GDP in Europe in 2000**

Source ACARE [Ref 1]

This profitable impact on the economy of airport activities explains that Regions are in general interested in having airports. Nevertheless the potential air traffic of some European regional area is too low for justifying the implementation of an airport. In this case, the creation of an HST line linking some localities to a new or existing airport could be a solution. Not only these people living in remote areas would have an easy access to other regions and other countries, but people living elsewhere could also easily access these remote areas which would increase the competitiveness of regions.

Unfortunately no available study exists on the economic impacts of intermodality between air and the other transport modes. We therefore propose in this section to underline what could be the economic impacts related to the improvement of the accessibility of airport from other regional areas, thanks to the creation of an HST line connecting the airport.

### 3.5.3.1 Impact on employment

As ACI [Ref 2] affirms that “The role of airports in promoting leisure and travel can make a valuable contribution to social inclusion”. In 2001 the total on-site employment at European airports was around 1.2 million. On average for 1000 on site jobs supported by European airports there are around 2100 indirect/induced jobs supported nationally, 1100 indirect/induced jobs supported regionally and 500 indirect/induced jobs supported sub-regionally (Source ACI [Ref 2]).

When analysing the contribution of airport activities on the European level of employment, ACARE [Ref 1] concludes that in 2000, 0.19% of the European employment level was related to airports activities.

<table>
<thead>
<tr>
<th>Airports</th>
<th>Direct effect</th>
<th>Indirect effect</th>
<th>Induced effect</th>
<th>Total impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contribution to employment in percentage</td>
<td>0.07%</td>
<td>0.05%</td>
<td>0.07%</td>
<td>0.19%</td>
</tr>
</tbody>
</table>

**Table 13: Impacts of airport activities on employment in Europe in 2000**

Source ACARE [Ref 1]

We can then assume that when facilitating the access to large airport of regional people, the HST line would allow them to get an employment at airport. In addition, the presence of this rail link to the airport could also attract the implementation of companies in remote areas. This would increase the number of indirect/induced jobs supported regionally and nationally.

### 3.5.3.2 Impact on tourism

Tourism is an increasingly important sector in the European economy. For certain countries, air transport can be the only mode by which tourists access the country. Airports play therefore an important role in making the development of inbound tourism possible. For instance 70% of foreign
tourists to the United-Kingdom arrive by air.

<table>
<thead>
<tr>
<th>1,995,630 visitors</th>
<th>15,641,763 nights</th>
<th>1.46 €bn income</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.9 nights average stay</td>
<td>€93 per night</td>
<td></td>
</tr>
</tbody>
</table>

The total impact of tourism through Nice Airport into the economy of the Alpes-Maritime Region amounted to €1.46 billion.

Figure 20: Air tourist expenses in housing at Nice
(source ACI [Ref 2])

Tourism expenditure from visitors arriving by air is not easy to evaluate since it is impossible to know how much tourists have spent during their stay. When only considering the housing expenses, Nice airport has evaluated that the 2 million of Nice visitors spend 1.46 Billion Euros. We can therefore expect that the presence of a high speed line linking the airport to remote regions could attract tourists in these regions and as a consequence increase theirs incomes. Hence as airports, airport-rail links could become catalytic impact on tourism.

3.5.3.3 Impact on vital services

As for an airport, the presence of a high speed rail link with a large airport should allow to finance vital services such as hospitals, colleges, etc. Indeed if this link allow to increase the level of employment of people of remote areas and would also increase the level of tourism in this area, we can expect that new companies will be created according to the needed of people living in this area and of tourists. The creation of such an airport-rail link could then have a profound quality of life implication.

3.5.4 Impact on safety

As for all transport modes, using airport intermodal transports have to be safely for passengers. This means that not only safe transports made by each transport modes but also safe transfer between modes. Transfers between modes have to be as safe as transfer within a single mode. When providing recommendations for improving the safety level of air/rail intermodal transports, RAIFF [Ref 59] recommends to “increase information on the liability coverage along the air-rail intermodal travel chain (identity of the carriers assigned to bear liability, information on any need to exchange part of
the ticket and the conditions of carriage and all relevant liability provisions applicable to each leg of the journey).”

Nevertheless IARO, ATAG and ACI [Ref 38] thinks that at the current time “passengers making an air-rail journey are travelling very safely”. According them, one of the main safety problem related to airport intermodality could be that a significant number of air rail links have part of their route in tunnels. They evaluate that safety issues would include:

- One person operation in tunnels allowing to evacuate the train if necessary
- The possibility for the line controller to speak to passengers though the on-train public address and put their mind at ease. This is for instance the case on Hong Kong airport Express line where the Operations Control Centre can make direct announcements to passengers on all trains.
- Being vigilant with dangers associated with two-way working on separate tracks in the same tunnel. Indeed, danger could occur if passengers have to evacuate the train while another train is coming on the other track and could hit them, or if a derailed train is hit by another
- Being vigilant with fire in tunnels which is a key safety issue

### 3.5.5 Impact on passengers

When taking into account the economic actors (transport operators, States, European Commission), the passengers as well as the resident, the work package 1 goes wider than the rest of the study. When elaborating evolution scenarios for the airports of the future in work-packages 2 and 3, we will have to focus on one perspective. The passenger perspective will then be retained.

In this context it is interesting to study more precisely the impact on passengers of airport intermodality. Unfortunately literature dealing with this aspect is not available at the current time. It is therefore impossible to provide an evaluation of these impacts. However, it is possible to underline how these impacts could be assessed.

KELLY T, WYNNE N., SOTO A., KRUPA M [Ref 42] define the consumer welfare as the benefit a consumer gets from consuming a good minus what he paid when buying this good. The difficulty is that each consumer welfare corresponds to his value judgement which can not be compared with another consumer on scientific grounds. The consumer welfare being hardly valuable the economic tool used for measuring it is the consumer surplus. The consumer surplus is the difference between what a consumer is willing to pay and what a good actually costs. Hence the consumer surplus measures the extra pleasure from a transaction in money unit (for instance Dollar or Euro).

In the case of intermodal transports the price the passenger is willing to pay, takes into account the passenger value of time as well other criteria for which passengers attach values. These criteria already presented in section 2.3.2 are:

- Connection issues at interchange points
- Comfort and on board services
- Service integration between modes or between operators
- Information services
- Security, reliability and delays

These criteria as well as their value differ between passengers since they each have their own preferences. Nevertheless there are similitude in preferences according to passengers categories. For instance, as stressed in section 2.3.2, leisure passengers are less sensitive to the on-board services and total transport time than business passengers. This would mean that an increase in the total transport time would reduce business passengers’ surplus in higher proportion than it would affect leisure passengers’ surplus. On the same time, a decrease in the on-board services would more reduce...
business than leisure passengers surpluses. As shown in section 2.3.2 the two most important parameters in modal choice are time and price. This means that if we assume constant prices, the impact on passengers could be estimated to some extent by using the value of time.

Impact of the use of airport intermodal transport on passengers could therefore be theoretically determined by evaluating the variation on passengers surpluses. These surpluses being difficult to measure, the real impact on passengers could be difficult to assess. However, studies on the variation of the demand level following changes in transport supply could help to better know the impact on passengers.
4 Concluding remarks

In literature, the term “intermodal” transport applied to passengers using successively air and other transport modes is used equally for the airport access to the city centre or for the integration of the airport in the regional or national network of other transport modes. As the implications of both types of airport intermodality are different in terms of investment, passenger needs, operators coordination, transport policies, etc., we have chosen in this study to differentiate between them. In the case of airport access, the relevant modes to study are all public modes. In the case of integration of the airport in the regional or national network, only rail is relevant (and particularly high speed train), since bus services on long distances are quite rare in Europe, and do not seem to become more prominent in the future. Conversely, air rail intermodality seems to offer promising opportunities for the future, and we have focused on this subject in this work package, except in the case of airport access.

This differentiation between airport access and the integration in the regional or national network appears particularly important when analysing the demand for airport intermodal transports. Indeed if the different transport modes allowing to access the airport from city centre (i.e. rail and bus transports) are not competitors of the air transport, this competition exists when interconnecting the airport to the regional or national rail network. As a consequence the passenger demand features differ according to the type of airport intermodality. If the time journey is always an important factor influencing their choice, the value of time differs according to the category of airport intermodality. In addition, the residency status of the traveller is particularly relevant for the airport access since it is taken into account in the propensity to choose a ground access mode other than the automobile. Besides the journey time and price, distance, speed, baggage transfer, fares and passenger comfort are also crucial for travelling decisions. Nevertheless there is a lack of studies taking into account all these aspects which are particularly important in the demand for air/HST intermodal transport. Studies often deal with the passenger preferences between air and HST transport modes but not on the passenger preferences between direct connection and combined transport modes. In addition, the lack of public information on figures on the passenger demand evolution for intermodal transport does not facilitate the demand analysis.

This decomposition in two categories of airport intermodal transport is however not considered by the European Commission which only considers the intermodality between high-speed train and air transport. In a large context of achieving a better balance between transport modes, the commission would like to increase the share of rail, control the growth in air transport, and limit the share of road transport. Intermodality is seen here in a very strong sense, as a way of limiting road or air traffic, both responsible for congestion and air pollution. However, the demonstration that airport intermodality would have significant positive impacts on congestion and pollution is not obvious. In particular airports and airlines interviewed by IATA [Ref 39] think that air/rail intermodality can have a limited effect on airport congestion. They expect that free slots would be kept by airlines in order to increase their services on markets other than the short-haul (mainly on the long-haul market). Hence intermodality would lead to a reallocation of the airport slots in terms of destinations. The IATA study only takes into account the opinion of passengers and air operators but there is a lack in the literature on studies estimating the real impact of air/rail intermodality on airport congestion. In addition, authors having performed studies on the environmental effects of intermodality do not all agree when quantifying the impact on air pollution. This discord is not only due to the difficulty of measuring the air pollution but also to the evaluation of the social cost per pollution unit. Different unit costs leads to different impact evaluation and leads some authors to conclude that social environmental cost of air transport would be lower than social environmental cost of rail transport…

Despite the fact that impacts of airport intermodality have not yet been clearly quantified, developing the air/rail intermodality remains an objective for numerous European states. However, we can
consider that one of the major obstacles to a large development of intermodal transport is the funding problem. Indeed, building railways involves large investments in railway infrastructure which can sometimes put a brake in the development of intermodal infrastructures. As the participation of the European Commission and of the national governments to the project financing may not be sufficient the possibility of private funding can have a large impact on the project realisation. One solution to convince airport operators to finance part of the project authorities could be to allow exclusive agreement between air and railway operators. Without this exclusive agreement, the dominant airline could find it less interesting since other airlines could conclude agreements with the railway operators and benefit from the intermodal link. The railway operator would also be more interested in financing with possibility of an exclusive agreement, especially if this agreement leads to the abandon of the route by the airline.

In addition, independently of funding aspects, the possibility of signing an exclusive agreement is an essential element for motivating the cooperation between railway and airline operators. Indeed airlines would be more ready to conclude an intermodal agreement with a railway company if it is certain that its rivals will not be able to negotiate other agreements. At the same time, the railway company would be all the more interested in concluding an exclusive agreement that the airline stops operating or reduces its frequencies on the considered route. The agreements between operators concerning specific routes, relations between operators can become complex. They indeed can be complementary in the market for connecting passengers on hub airport and at the same time rivals in the market of point-to-point travel. In this situation it is not easy to determine where the limit between competition and cooperation for both transport modes is, but the current existence of intermodal agreements tends to show that this limit exists.

By producing a state of the art of airport intermodality, the work-package 1 provides important information on such intermodality features in operational, financial, politic terms. This knowledge of these features will be essential when determining the role of intermodality for the airports of the future in the two next work-packages. However, when taking into account the economic actors (transport operators, States, European Commission), the passengers as well as the resident, the work package 1 goes wider than the rest of the study. When elaborating evolution scenarios for the airports of the future in work-packages 2 and 3, we will have to focus on one perspective. The passenger perspective will then be retained.