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Factors of air-rail passenger intermodality

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Abstract

European transport policy promotes intermodality as a means of improving efficiency and sustainability. This study looks into passenger air-rail intermodality at airports which are directly integrated into long-distance rail networks and focuses on intermodal journeys in which the rail trip doesn't serve the purpose of city-centre to nearby airport access, but rather makes up a substantial leg of the journey, potentially substituting short-haul air feeders and expanding airport catchment areas. Air-rail intermodality projects involve considerable capital and operating costs and require ambitious goals and strong cooperation among actors. Although best practice guidelines exist for intermodality in general, there doesn't seem to be one best solution for air-rail intermodality success. By examining literature, European intermodal products and rail stations at airports, we propose five critical success factors: infrastructure integration, network context, overall travel time and transfer time, integrated ticketing and information. Governance factors were also found to be a key determinant of success for planning, implementing and operating these multi-operator projects which require high levels of coordination. Case studies examined best practice (Frankfurt airport) and compared a successful case with one which is not so successful (Paris-CDG versus Lyon Saint-Exupéry). Result transferability to Portugal was analyzed, focusing on Lisbon airport. As a result, we suggest three issues be taken into account when assessing the integration of Lisbon airport into the high-speed rail network – sufficient demand to justify adequate rail frequencies, sufficient provision of long-haul flights from Lisbon airport to capture demand and the existence of operator interest in offering intermodal products.

Keywords: Air-rail intermodality, intermodal integration, substitution, airports, air transport, rail transport

Resumo

Este estudo debruça-se sobre intermodalidade aero-ferroviária no transporte de passageiros em aeroportos diretamente integrados na rede ferroviária de longa distância e foca viagens intermodais em que a porção ferroviária não serve o acesso ao aeroporto a partir do centro da cidade, correspondendo sim a uma parte substancial da viagem e podendo substituir voos *feeder* de curta distância e alargar a área de influência do aeroporto. Os projetos de intermodalidade aero-ferroviária envolvem custos de investimento e operação consideráveis e exigem a definição de metas ambiciosas e uma cooperação forte entre atores. Embora existam diretrizes para a intermodalidade em geral, não parece haver uma receita para o sucesso deste tipo de projetos em particular. Ao examinar literatura, produtos intermodais europeus e estações ferroviárias nos aeroportos da Europa, foi possível propor cinco factores críticos de sucesso: integração da infraestrutura ferroviária e aeroportuária, contexto das redes, tempo de viagem e tempo de transferência entre modos, bilhete único e informação. Examinou-se um caso de melhor prática (aeroporto de Frankfurt), comparou-se um caso de sucesso com um menos bem sucedido (Paris-CDG contra Lyon Saint-Exupéry) e procurou-se transferir os resultados para o aeroporto de Lisboa. Como resultado, sugerem-se três questões a ter em conta na avaliação da integração deste aeroporto na rede ferroviária de alta velocidade – procura suficiente para justificar frequências ferroviárias adequadas, provisão suficiente de voos de longa distância no aeroporto de Lisboa para capturar a procura e a existência operadores interessados na oferta de produtos intermodais.

Palavras-chave: Intermodalidade aero-ferroviária, integração intermodal, substituição, aeroportos, transporte aéreo, transporte ferroviário

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Acronyms

ACI	–	Airports Council International
ADIF	–	Administrador de Infraestructuras Ferroviarias (Spain)
AKL	–	Auckland Airport, New Zealand (IATA code)
AMS	–	Schiphol Airport (Amsterdam), Netherlands (IATA code)
ANA	–	Aeroportos de Portugal (Portugal)
ARN	–	Stockholm-Arlanda Airport, Sweden (IATA code)
ASK	–	Available seat kilometre
ATAG	–	Air Transport Action Group
ATH	–	Athens International Airport, Greece (IATA code)
BCN	–	Barcelona Airport, Spain (IATA code)
BNE	–	Brisbane Airport, Australia (IATA code)
BOS	–	Logan International Airport, Boston, USA (IATA code)
BRU	–	Brussels Zaventem Airport, Belgium (IATA code)
CAN	–	Guangzhou Baiyun International Airport, China (IATA code)
CBA	–	Cost-benefit analysis
CDG	–	Paris-Charles de Gaulle Airport, France (IATA code)
CGN	–	Cologne Bonn Airport, Germany (IATA code)
CPH	–	Copenhagen Kastrup Airport, Denmark (IATA code)
CRS	–	Computer reservation system
DB	–	Deutsche Bahn (Germany)
DEN	–	Denver International Airport, USA (IATA code)
DGAC	–	Direction Générale de l'Aviation Civile (France)
DSB	–	Danske Statsbaner (Denmark)
DUS	–	Düsseldorf International Airport, Germany (IATA code)
EC	–	European Commission
EDI	–	Edinburgh Airport, United Kingdom (IATA code)
EU	–	European Union
Eurocontrol	–	European Organisation for the Safety of Air Navigation
Eurostat	–	Statistical Office of the European Communities
FCO	–	Leonardo Da Vinci International Airport, Fiumicino (Rome), Italy (IATA code)
FRA	–	Frankfurt International Airport, Germany (IATA code)
FRAPORT	–	Frankfurt Airport Services Worldwide (Germany)
GUIDE	–	Group for Urban Interchanges Development & Evaluation
GVA	–	Cointrin International Airport, Geneva, Switzerland (IATA code)
HEL	–	Helsinki Airport, Finland (IATA code)
HERMES	–	High efficient and reliable arrangements for crossmodal transport
IAD	–	Washington Dulles International Airport, USA (IATA code)
IATA	–	International Air Transport Association
ICE	–	Intercity express
ICN	–	Incheon International Airport (Seoul), South Korea (IATA code)
IST	–	Sulaimaniyah International Airport, Iraq (IATA code)
ITA	–	Institut du transport aérien
JFK	–	John F. Kennedy International Airport, New York, USA (IATA code)
KITE	–	A knowledge base for intermodal passenger travel in Europe
LAS	–	McCarran International Airport, Las Vegas, USA (IATA code)
LAX	–	Los Angeles International Airport, USA (IATA code)
LCC	–	Low cost carrier

LCY	–	London City Airport, United Kingdom (IATA code)
LHR	–	London Heathrow Airport, UK (IATA code)
LINK	–	The European forum on intermodal passenger travel
LOU	–	Bowman Field, Louisville, USA (IATA code)
LYS	–	Lyon-Saint Exupéry Airport, France (IATA code)
MAD	–	Madrid-Barajas Airport, Spain (IATA code)
MAN	–	Manchester Airport, UK (IATA code)
MAV	–	Magyar Államvasutak (Hungary)
MIA	–	Miami International Airport, USA (IATA code)
MIL	–	All airports in Milan, Italy (IATA code)
MRS	–	Marseille Provence Airport, France (IATA code)
MUC	–	Munich Airport, Germany (IATA code)
MXP	–	Malpensa International Airport, Milan, Italy (IATA code)
NCE	–	Côte d'Azur International Airport, Nice, France (IATA code)
NMBS/SNCB	–	Nationale Maatschappij der Belgische Spoorwegen, Société Nationale des Chemins de fer Belges (Belgium)
NRT	–	Narita International Airport (Tokyo), Japan (IATA code)
NS	–	Nederlandse Spoorwegen (Netherlands)
NSB	–	Norges Statsbaner (Norway)
OSL	–	Oslo Airport, Gardermoen, Norway (IATA code)
PAR	–	All airports in Paris, France (IATA code)
PDX	–	Portland International Airport, USA (IATA code)
PEK	–	Beijing Capital International Airport, China (IATA code)
PHX	–	Phoenix Sky Harbor International Airport, USA (IATA code)
PIK	–	Glasgow Prestwick International Airport, UK (IATA code)
PVG	–	Shanghai Pudong International Airport, China (IATA code)
RAVE	–	Rede Ferroviária de Alta Velocidade (Portugal)
REFER	–	Rede Ferroviária Nacional (Portugal)
RENFE	–	Former Red Nacional de los Ferrocarriles Españoles (Spain)
RFF	–	Réseau ferré de France
ROM	–	All airports in Rome, Italy (IATA code)
SBB-CFF-FFS	–	Schweizerische Bundesbahnen, Chemins de fer fédéraux suisses, Ferrovie federali svizzere (Switzerland)
SFO	–	San Francisco International Airport, USA (IATA code)
SJ	–	Former Statens Järnvägar (Sweden)
SNCF	–	Société nationale des chemins de fer français (France)
STN	–	London Stansted Airport, UK (IATA code)
SVQ	–	San Pablo Airport, Seville, Spain (IATA code)
TXL	–	Berlin Tegel Airport, Germany (IATA code)
UK	–	United Kingdom
UL	–	Upplands Lokaltrafik (Sweden)
USA	–	United Stated of America
YUL	–	Montréal-Pierre Elliott Trudeau International Airport, Canada (IATA code)
YYC	–	Calgary International Airport, Canada (IATA code)
YYZ	–	Toronto Pearson International Airport, Canada (IATA code)
ZRH	–	Zurich Airport, Switzerland (IATA code)

1 Introduction

1.1 Purpose of this study

This study examines passenger air-rail intermodality. It focuses specifically on cases of infrastructure integration, where railway stations at airports directly connect the air networks with rail networks. This study explores the success factors of air-rail intermodality in long-distance travel where the rail trip doesn't serve the purpose of city-centre to nearby airport access, but rather makes up a substantial leg of the journey (Figure 1).

Figure 1 – Type of intermodal journeys this study will focus on

European policy has long insisted on intermodality (and more recently, on co-modality) as a means of promoting efficiency and sustainability. This study looks into a specific case of intermodality and looks for answers for the following question:

- Which factors determine air-rail intermodality success?

1.2 Methodology

This study is based on a desktop review of policies and relevant research and on case study analysis. It was carried out in 5 steps (Figure 2):

Step 1: Review of three important framework issues:

- European policy
- Actors and their motivations and concerns about air-rail intermodality
- Defining air-rail intermodality success

Step 2: Inventory of current situation

- Railway stations at airports in Europe
- Air-rail products on sale in Europe

Step 3: Identification of factors

- Literature review
- Identifying critical factors
- Relating factors with actors
- Relating factors with success domains

Step 4: Case studies

- Case selection
- Data collection
- Case study 1: best practice
- Case study 2: comparing opposite success cases
- Case study 3: transferability of results to Portugal

Step 5: Recommendations and notes on result transfer

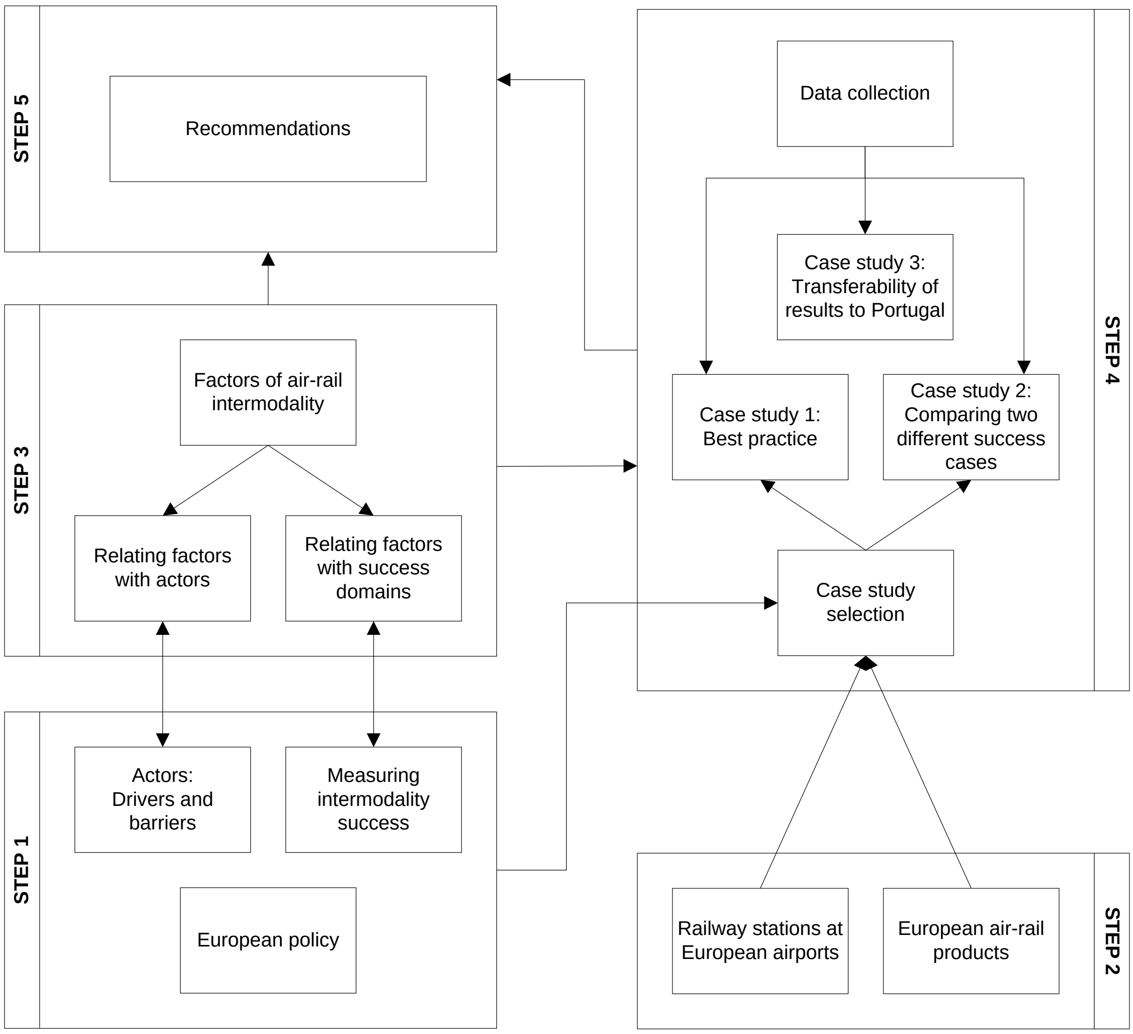


Figure 2 – Methodology schematics

2 Background

2.1 Air transport networks

There are two key concepts in the analysis of air transport networks: connectivity and interconnectivity. Button (2003) defines **connectivity** as the existence of a link between two points or nodes involving only those two nodes. In Figure 3, on the left, there is connectivity between A and B. The author defines **interconnectivity** as the existence of a link between two points or nodes which involves at least three nodes. In Figure 3, on the right, there is interconnectivity between A and B and K is a transfer node.

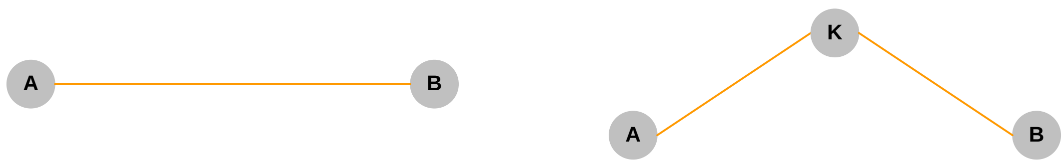


Figure 3 – Connectivity and interconnectivity
Source: Adapted from Button (2003), p. 12

Based on these concepts, one can easily distinguish **point to point** networks from **hub and spoke** networks: the former provide a direct service connecting A to B, the latter connect several Ai and Bi nodes to a transfer node K – the *hub* – where interconnecting Ai-Bi passenger traffic is grouped and rearranged.

The key concept of hub and spoke networks is the consolidation of traffic flows from various origin airports (spoke links) on a hub from which flows are redirected (Janić, 2007). Typically, the hub has significant origin/destination traffic, although conceptually this feature is not required to act as a hub – a platform to redirect passengers.

Figure 4 illustrates a network of n = 5 cities. By using point to point services, it would be necessary to operate n (n-1) / 2 = 10 routes to ensure connectivity between all the cities – AE, BE, CE, DE, AB, AC, AD, BC, BD, CD. By adopting a hub and spoke configuration centered on E, it is possible to establish interconnectivity between all cities operating only n-1 =4 routes– AE, BE, CE, DE.

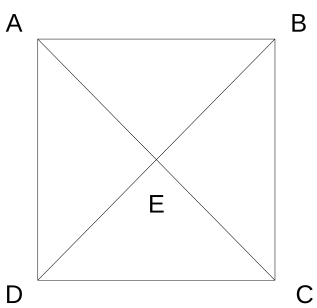


Figure 4 – Possible links between 5 nodes
Source: Button (2002)

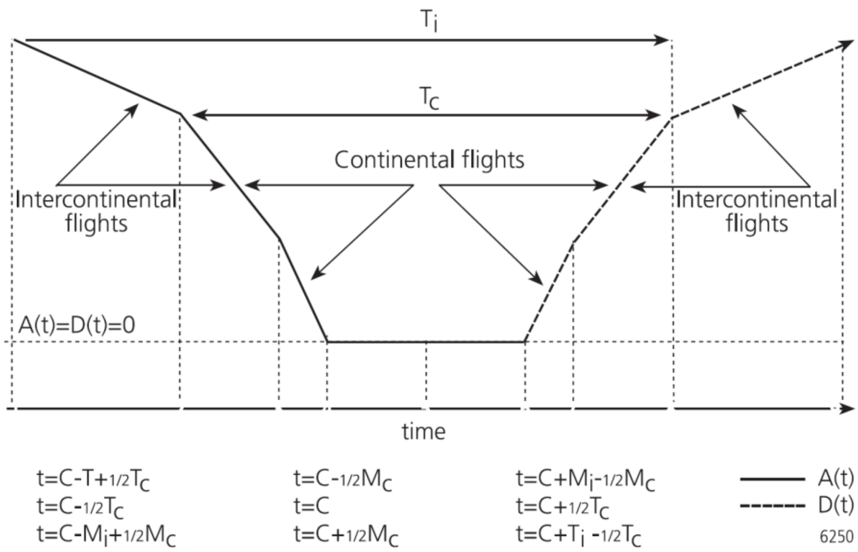
Hub and spoke networks impose additional time costs on the user by increasing the distances involved and by introducing a stopover at the central point – node E in Figure 4 (Button, 2002). However, the overall travel cost for the user is potentially reduced on this network configuration. In fact, the traffic flow from A to E will be the sum of all streams of traffic originating in A (AB, AC, AD, AE), which usually allows for a unit cost (per passenger) reduction due to various economies on the cost side. The user benefits from this phenomenon when its impact is to reduce the price of the trip.

Additionally, this configuration makes it possible to market certain connections that would be commercially unviable in point to point and thus would only exist if subsidized. If the connection from A-B has a demand of 5 passengers / day, it may not make sense to maintain a commercial service between these points; and if the same happens with other potential links originating from A (AC, AD and AE), A ceases to be served by air services unless subsidy mechanisms are resorted to. By adopting hub and spoke networks, all passengers departing from A will have to go through E, where they will be redirected to their destination. In this situation, it is possible that the sum of the demand originating from A will be enough to make it profitable to operate the air link commercially.

Further, in a scenario in which long-distance flights depart from E, the connections to E in Figure 4, known as *feeder* flights, allow feeding the larger capacity intercontinental flights with passengers. The feeder flights themselves may not be lucrative, but as feeders for long-haul (profitable) flights they are profitable (EC, 1998).

Also, this configuration has the potential to increase level of service at small airports by increasing frequency and convenience of links. If A-B traffic can justify one daily flight, passengers will have one schedule option for their outward trip and one for their round trip. By consolidating all demand from A in E (and from B as well), it might be possible to assure a greater link frequency.

So, in short, hub and spoke networks will concentrate spatially on one or more hubs where passengers can transfer between flights in a given time window. Typically, operators will coordinate arrivals/departures timetables with the purpose of maximizing the opportunities for transfer (Burghouwt, 2007), thus generating a number of *waves* of connecting flights throughout the day at the hub (Figure 5). This system is a complex structure of arrivals and departures organized in a way that passengers on any arriving flight can connect with all departing flights (Bootsma, 1997).



A(t) = number of flights that still have to arrive at the hub at time t
D(t) = number of flights that still have to depart from the hub at time t
C = wave centre
Mi = minimum connecting time for intercontinental flights
Mc = minimum connecting time for continental flights
Ti = maximum connecting time for intercontinental flights
Tc = maximum connecting time for continental flights

Figure 5 – Arrivals/departures wave structure at a hub
Source: Burghouwt & de Wit Burghouwt and de Wit (2005), p. 86, based on Bootsma (1997)

Air transport network analysis uses spatial as well as temporal criteria. Spatial analysis of air transport networks is based on graph theory (in particular on measures of connectivity), in models of location / allocation for hubs and measures of concentration and dispersion. Time based analysis usually focuses on the ratio between direct and indirect travel time and on the wave structures defined above (Burghouwt, 2007).

In fact, air transport networks develop as combinations of different forms. One example is the case of hub and spoke structures in which some of the nodes are interconnected by point to point services. Figure 6 shows examples of air transport network configurations sorted by spatial concentration and temporal coordination of services.

On any of the configurations presented on Figure 6, it is straightforward to envision that any of the *air spokes* may be replaced by a *rail spoke*, as long as rail infrastructure and service are in place and adequate transfer is provided, as in the case of airplane to airplane – luggage transfer, integrated ticketing, people moving solutions for larger distances between terminals, etc. Also, it follows that additional *rail spokes* may be added to the existing networks for destinations without airports. Further we will discuss in what conditions air and rail can be integrated, after a necessary review of how these two modes of transport interact.

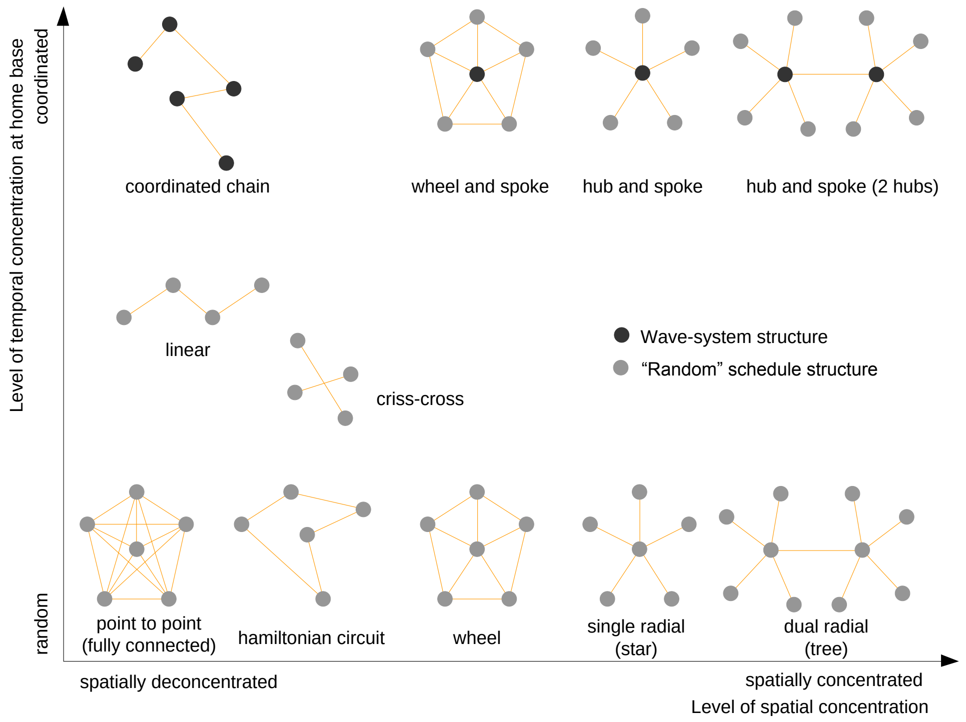


Figure 6 – Air transport network configurations

Source: Adapted from Burghouwt (2007)

2.2 Interaction between air and rail

It is possible to describe three kinds of interaction between air and rail:

- Competition
- Complementarity
- Cooperation, a specific case of complementarity

2.2.1 Competition

Competition between air and rail on an origin-destination pair typically involves different operators. One example is the link between Paris and London, where high-speed train service Eurostar competes with the air services of several airlines (Figure 7).

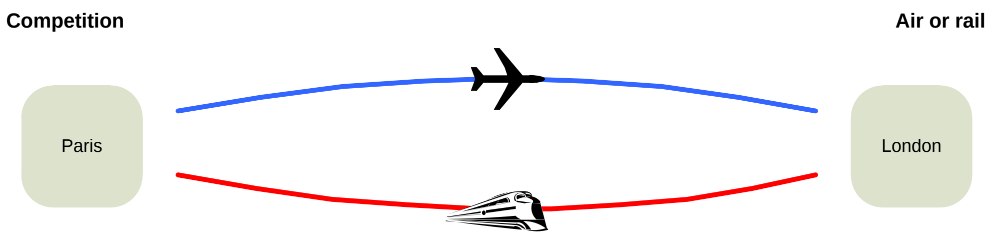


Figure 7 – Example of competition between air and rail

Source: Adapted from Cokasova (2006), p. 12

There is competition between two modes on a link when they are mutually replaceable, therefore satisfying the same transport need. The passenger can choose one mode or the other to get from A to B, and it is possible to identify the factors which determine the market share of air and rail in those situations (EC, 2006b):

- Travel time (rail excess travel time in relation to air, Figure 8)
- Terminal access time and cost
- Ticket price and conditions
- Punctuality and reliability
- Service quality aboard train/plane and at terminals
- The existence of *low-cost* alternatives

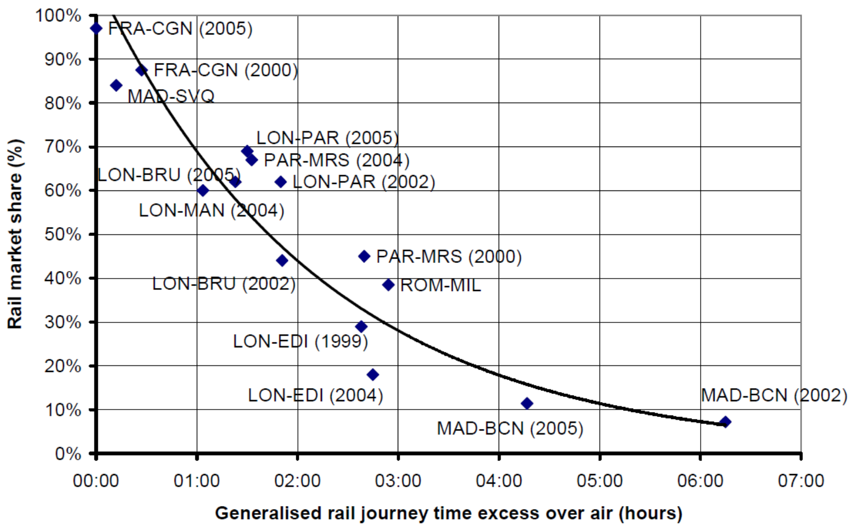


Figure 8 – Rail market share vs. generalized rail journey time excess over air
Source: EC (2006b), p. 16

Up to 3 hours journey time, the speed advantage of air is reduced by the rigidity of its transport production process (Chi, 2004). An airplane trip requires a large number of operations, especially for safety reasons. In shorter trips, the proportion of journey time spent on land is very high, including among other operations the airport access trip and 1 to 2 hours in the airport for check-in and safety checks[1]. Additionally, Chi (2004) points out that when 19,9% of flights depart with delays over 15 minutes, air is at a disadvantage in relation to rail in terms of time/price, since rail registers only 4 to 8% delays over 14 minutes and, in most European cases, rail stations have better accessibility than airports (data for 2002 presented by Chi).

[1] With electronic check-in and other self-check-in solutions, these 2 hours can be reduced, in particular for domestic flights (Chi, 2004). One example is the Puente Aéreo between Madrid and Barcelona, which allows travelers to arrive up to 20 minutes before take-off and often boards passengers 5-10 minutes before take-off (EC, 2006). Already in 1998, while analyzing the case of Antwerp airport, EC (1998) stated that many regional airports would be able to offer a check-in up to 10 minutes before take-off.

EC (1998), among others, refers to a study by the *Institut du Transport Aérien* (ITA) which focused on 154 routes in 1991, analyzing time and price. This study drew conclusions on the journey distance intervals where air and rail compete (Figure 9):

- On trips up to 250km, rail is the market leader
- Between 250 and 600km, air and rail compete but the market share of rail is larger
- Between 600 and 1000km, air and rail compete but the market share of air is larger (it is possible for high speed rail to travel 1000 km in 3 hours)
- Over 1000km, air is the market leader

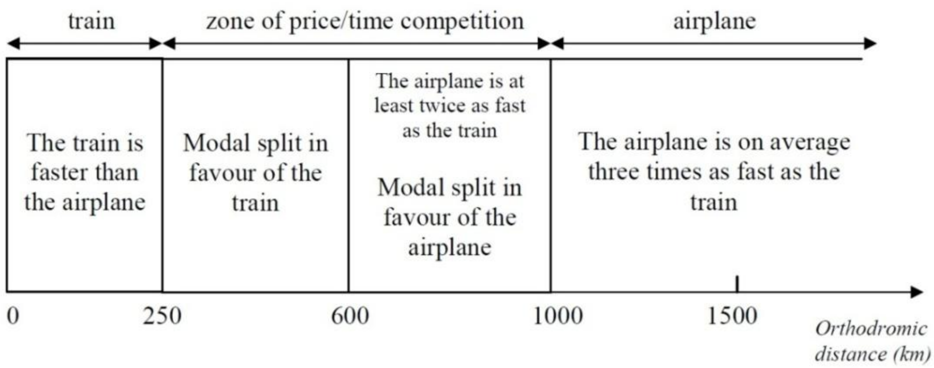


Figure 9 – Distance intervals at which air and rail compete, according to the 1991 ITA study
Source: Chi (2004), p. 7

In Europe, competition between air and rail occurs in high origin-destination transport volume corridors/markets, such as Madrid-Seville, Madrid-Barcelona, London-Paris, London-Brussels, Frankfurt-Cologne, Paris-Marseille, London-Manchester and London-Edinburgh, where, on average, a high-speed train with a journey time between 1 and 3 hours can capture 30-90% of the air transport market (Janić, 2011).

These cases of competition between air and rail are widely studied and documented. It is possible to observe for the case of Madrid-Seville, that with the opening of the high-speed rail service between the two cities, the air market share dropped from 40% to 13% and is recently composed mainly of transfer passengers (Eurocontrol, 2004b).

An additional point on air-rail competition related to the subject of rail stations at airports is that, considering that the majority of airports is located near a city and has good accessibility to multiple destinations in the area, a railway station at an airport can operate independently of air services, thus providing a high-speed alternative mode (which may not yet exist in the area). Therefore, the introduction of railway stations in airports can promote competition between modes.

2.2.2 Complementarity

Complementarity between modes on a link typically involves different operators. Often rail complements air, offering a link from the airport to the final destination of the journey. One example is a journey from Paris to Malmö composed of an air link from Paris to Stockholm-Arlanda airport followed by a train link between Arlanda and Malmö. In this particular case, the air service operator is Air France and the train service operation is SJ (Figure 10). For complementarity to occur, it is not compulsory that both operators coordinate arrivals and departures nor that they integrate the tickets, but it must be possible to use their travel services successively to complete the journey:

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

[EC (1998), p. 59]

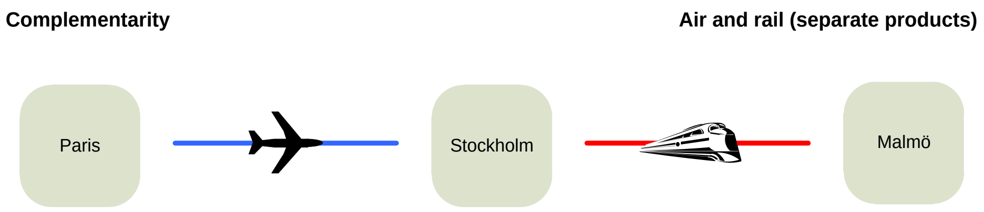


Figure 10 – Example of complementarity between air and rail
Source: Adapted from Cokasova (2006), p. 12

2.2.3 Cooperation

Cooperation between modes on a specific link involves integrated products, and typically different operators. This is a specific case of complementarity, that is, rail complements air by replacing or adding a short/ medium distance connection which is integrated with the air service in one product. One example is the New York-Stuttgart journey sold by Lufthansa: the ticket includes both links (New York to Frankfurt by air and Frankfurt to Stuttgart by rail) and there is only one luggage check-in and one luggage check-out, despite the stopover in Frankfurt.

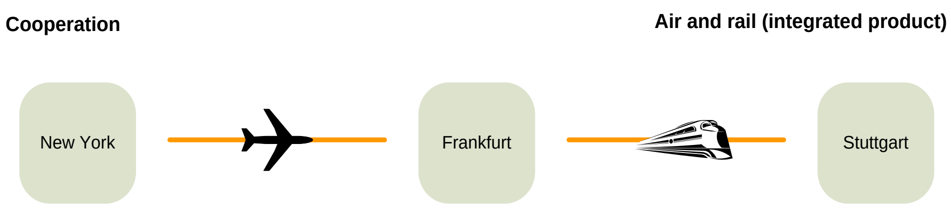


Figure 11 – Example of cooperation between air and rail
Source: Adapted from Cokasova (2006), p. 12

In chapter 4.2, we describe some cases of integrated air-rail products which operate currently in Europe.

A further note on the metrics of this issue, following the conclusions of the ITA study, is that Givoni and Banister (2006) found that on high speed rail routes of under 600km, where the rail route is not more than 20% longer than the aircraft route and the average rail speed along its route is at least 250 km/h, the operation of airline and railway integration is beneficial to airlines, passengers and the environment.

It should be noted for complementarity (and, in some cases, cooperation) that those services will be competing for their routes' markets against possibly direct air service alternatives or two-leg air services.

2.3 Defining air-rail intermodality

It follows from the definitions of cooperation and complementarity on the previous chapter that these occur in **intermodal** travel, where the intermediate node acts as a platform for mode transfer.

The European Commission's definition of intermodality is as follows:

> ***Intermodality*** *is a characteristic of a transport system that allows at least two different modes to be used in an integrated manner in a door-to-door transport chain. Intermodality is a quality indicator of the level of integration and complementarity between modes, which provides scope for a more efficient use of the transport system.*

[EC (1997), p. 1]

The concept of co-modality reinforces this latter aspect of efficiency. By highlighting efficiency, co-modality sets as a goal the optimal use of the transport system – the optimization of each mode and the integration of modes for seamless transport. In a co-modality framework, modal shift occurs where it is socio-economically desirable (Riley and Kumpoštová, 2010), in what concerns resource utilisation:

> ***[C]o-modality****, i.e. the efficient use of different modes on their own and in combination, will result in an optimal and sustainable utilisation of resources.*

[EC ((2006c), p. 4]

Project KITE goes beyond a technical definition and defines passenger intermodality as a policy and planning principle:

> ***Passenger intermodality*** *is a policy and planning principle that facilitates the combination of different modes in order to enable seamless travel.*

[KITE (2007), p. 7]

Eurocontrol (2004a) lists two defining features of intermodal transport:

- The use of more than one mode of transport to complete a journey;
- The coordination between those modes of transport in providing a travel service.

In air transport, Eurocontrol (2004a) distinguishes between intermodal travel in which one mode solely performs **airport ground access** and intermodal travel in which the land leg corresponds to a substantial part of the trip. The authors argue that this distinction is important because each type of intermodality has different implications in terms of investment, needs of passengers, operators and coordination of transport policies, thus adopting the following categories:

- **Type 1 intermodality** refers to airport ground access from the nearest urban area. One example of a type 1 intermodal journey is a home-airport trip by bus followed by an air trip to another continent.
- **Type 2 intermodality** results from the integration of an airport in the regional or national transport networks, particularly the high-speed rail network. An example of a type 2 intermodal route is illustrated in Figure 11, from New York to Frankfurt by plane and then by train to Stuttgart.

This study focuses on type 2 intermodality, specifically on the integration of air and rail.

In type 2 intermodality, AEROAVE (2011) considers medium distance and long distance services separately:

- Short/medium distance services with lengths of 100-300km, in which rail works as a feeder for the airport, mostly considered to impact on airport competition;
- Medium/Long distance services with lengths of 300-800km, in which rail works as a substitute for air, mostly considered to impact on air-rail mode competition.

2.4 European policy framework

Intermodality has been an important goal of EU transport policy in the past decade. In fact, the first references to passenger intermodality in EU policy appear in the previous decade, in the 1995 Green Paper on the *Citizen's Network* (EC, 1995), whose purpose was to make public passenger transport more attractive in Europe by placing passenger needs at the centre of the decision process. This paper determines the need to offer integrated and intermodal services for passengers.

By the end of the 1990 decade, development of railway infrastructure at airports and between them was expected to fulfill at least three objectives (EC, 1998):

- To generally improve efficiency of airport ground accessibility.
- To improve surface connectivity between particular airports as a precondition for replacement of short haul flights with rail services
- To further contribute to the development of integrated air-rail systems in Europe, in which high-speed rail would certainly play complementary roles by carrying out shorter segments of some intercity journeys.

In 2001, the EU White Paper *European transport policy for 2010: time to decide* (EC, 2001) set a common transport policy for the European Union for the first decade of the 21st century. The main goals for passenger transport were the development of safe, efficient and socially as well as environmentally satisfactory transport services. The White Paper identified integrated ticketing, baggage handling and continuity of journeys as the key priority issues for intermodal passenger transport. The document also proposes several instruments to achieve policy goals: market liberalization, development of transeuropean transport network infrastructure, promotion of effective pricing policies and implementation of information and communication technologies in the transport sector.

Although a large bulk of research and action in the 2000 decade was done in the field of freight intermodality, passenger intermodality was also given considerable relevance. In pursuing the 2001 White Paper policy, the EU funded research into how competition between air and rail can shift into complementarity in order to produce capacity gains and into the possibility of extinguishing air routes on links where competitive high-speed services exist and transferring air capacity to links where no high-speed rail service exists (EC, 2001). At the time, the EU also funded many infrastructure projects in the context of the transeuropean transport network.

In 2004, the former EU Directorate-General for Transport and Energy commissioned the study *Towards passenger intermodality in the EU* which mapped priorities and created an action plan in which the rail/air combination was a priority mode pair (EC, 2004).

In 2006, the mid-term review of the 2001 White Paper introduced the concept of co-modality and focused on four key points: a high level of mobility, attention to environmental protection and energy security, innovation for efficiency and sustainability and international connection beyond the EU (EC, 2006c).

Further research into passenger intermodality was funded, of which some projects stand out for their specific relevance to air-rail intermodality: *KITE: a knowledge base for intermodal passenger travel in Europe* (KITE, 2007) and *LINK: the European forum on intermodal passenger travel* (LINK, 2009).

The 2009 EC communication *A sustainable future for transport* (EC, 2009) was the main outline for a new White Paper for transport common policy. Again intermodality relevance to EU policy was reaffirmed as the EC stressed the need to focus on new technologies and on the integration of the different transport modes into a single system in a more integrated internal market where competition is fully granted.

Current EU transport policy was adopted by the EC in 2011, with the publication of the 2011 White Paper *Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* (EC, 2011). Seamless door-to-door mobility is one of the initiatives proposed by the EC to achieve efficiency, specifically in the field of service quality, comprising the definition of measures necessary for further integrating different passenger transport modes and the development of framework conditions to promote the development and use of intelligent systems for interoperable and multimodal scheduling, information, online reservation systems and smart ticketing.

3 Actors in air-rail intermodality – drivers and barriers

Air-rail intermodality impacts society in general and many different groups in particular. In order to identify the factors which will contribute to the success of air-rail intermodality in a context of infrastructure integration, it is important to understand what motivates intermodality for major actors:

- Passengers
- Airports
- Airlines
- Railway infrastructure companies
- Rail operators

At this point in our study, we will leave out secondary actors such as travel agents, policy makers and city managers, although they will be included later in our assessment of which actors are involved in success factors for intermodality. Some studies which come from a CBA background also add society as a whole as an important perspective in air-rail intermodality, driven by potential environmental and efficiency benefits.

The main references for this analysis are:

- Eurocontrol (2005b), which used interviews to understand drivers and barriers for air-rail intermodality for the actors we have defined, having also studied two others (European Commission and Member States and infrastructure private investors).
- Vespermann and Wald (2011), who used data obtained through questionnaires to airport operators and cluster analysis to identify airports' main motivations for air-rail intermodality and went on to classify airports according to them.
- IATA (2003), who also used questionnaires to understand drivers and barriers for actors in air rail intermodality.
- Givoni and Banister (2006), who studied the effects of intermodality, having focused on the Heathrow-Paris corridor by means of a CBA which estimated airline (operating cost), passenger (travel time savings) and society (environmental) benefits.
- HERMES (2011a), which focused on many short distance/long distance intermodality as well as longer range/long distance intermodality (but most of its findings are relevant for the type of intermodality our study is concerned with); its stakeholder survey and expert workshop, which included actors such as terminal managers, user associations, operators and public decision makers, looked into the barriers of intermodality.

Table 1 summarizes the drivers and barriers described in the following subchapters for each actor.

Actor	Driver	Barrier
Passengers	Cost	Reduction in modal choices

Actor	Driver	Barrier
	Travel time Quality of service	Lack of information Booking systems
Airports	Expanding catchment area Intention to increase airside capacity at the airport Meeting customer needs for a seamless transport chain Addressing environmental and landside congestion issues/targets	Car parking revenue loss Non reallocation of freed slots Catchment area overlap with other airports
Airlines	Possibility to efficiently substitute feeder flights by trains in order to free slots for more profitable routes Reduction of operating costs	Loss of control of the feeder routes Benefits to competing airlines Cost of the intermodality project Difficulties selling the intermodal product Complexity and costs not considered to be in accordance with the low cost model
Railway infrastructure companies	Development/expansion of global rail Optimal use of rail infrastructure Improving rail market share Getting into a global transport network	Funding the high infrastructure costs for intermodal projects Benefits to modal competitors (air transport)
Rail operators	Improving rail market share Improving the image of high-speed rail	Financial issues Benefits to modal competitors (air transport) Capacity issues

Table 1 – Drivers and barriers for major actors involved in air-rail intermodality
Source: Based on information from Eurocontrol (2005b), Vespermann and Wald (2011), IATA (2003), Givoni and Banister (2006) and HERMES (2011a)

3.1 Passengers

In the analysis of passenger drivers and barriers, Eurocontrol (2005b) notes that it is necessary to distinguish segments: business passengers have a high sensitivity to time while leisure passengers have a high sensitivity to cost factors. The study also refers to cultural differences between each country.

Cost considerations are a driver for passengers – if the cost of the intermodal trip is lower, passengers, especially leisure passengers, will be motivated for intermodality. Mode substitution can lead to travel time savings for passengers (Givoni and Banister, 2006). Shorter **travel time** will also motivate passengers, especially business passengers, its factors being the rail leg travel time, the transfer time between train and airplane and the compatibility of air-rail timetables. Finally, **quality of service** is also an important driver of intermodality, depending upon reliability, intermodal network coverage (number of interconnected destinations), baggage handling, integrated ticketing, on-board comfort, operator responsibility agreements (in case of delays or lost luggage, for example).

The introduction of intermodal products may decrease or even eliminate modal competition on certain routes, which entails a risk of higher prices and lower quality of service (Eurocontrol, 2005b). The **reduction of travel alternatives** is therefore seen as a barrier for passengers.

Lack of information is also considered a barrier to intermodality, in terms of marketing, and also in terms of information integration for travel planning – information about airline timetables is most often presented separately from rail timetables. This barrier extends to travel planning by agencies, as current **booking systems** don't offer codes for all rail stations and furthermore will usually show intermodal options last as they order products by length of the first leg.

3.2 Airports

Four main drivers can be defined for airports (Vespermann and Wald, 2011):

- Expanding catchment area
- Intention to increase airside capacity at the airport
- Meeting customer needs for a seamless transport chain
- Addressing environmental and landside congestion issues/targets

According to Vespermann and Wald (2011), it is possible to classify airports according to their motivations for air-rail intermodality (Figure 12):

- Cluster I airports stress the importance of **catchment area expansion**; they are mostly located in densely populated areas that stretch beyond nearby cities, so they can generate additional catchment by offering different means of transportation.
- Cluster II airports don't focus on a single driver, although they seem to value the **expansion of catchment area as well as meeting customer needs**; they are midsize European airports which usually already have a balanced modal mix.
- Cluster III airports stress above all the importance of **addressing environmental and landside congestion issues/targets**; they are mostly located in North America and focus mainly on city-centre links.
- Cluster IV airports stress the importance of **meeting customer needs** – they want to offer air-rail integration in order to obtain a heterogeneous modal split because they believe it best serves their customers (some also offer more complex products such as remote baggage check-in); they are located not only in Europe but also Asia/Oceania and America.

Despite different motivations, all airports that participated in Vespermann and Wald (2011)'s study support the idea that intermodal concepts represent an **important competitive advantage** for an airport. With a different approach, IATA (2003) interviewed large vs. regional airports to understand the effects they expected from air rail intermodality and found that large airports agreed with the above idea that railway network integration is a competitive advantage (against other airports), especially in polycentric areas. However, regional airports were cautious about the positive effects of air rail intermodality as they expected a much lower benefit/cost ratio than such services would at major hubs.

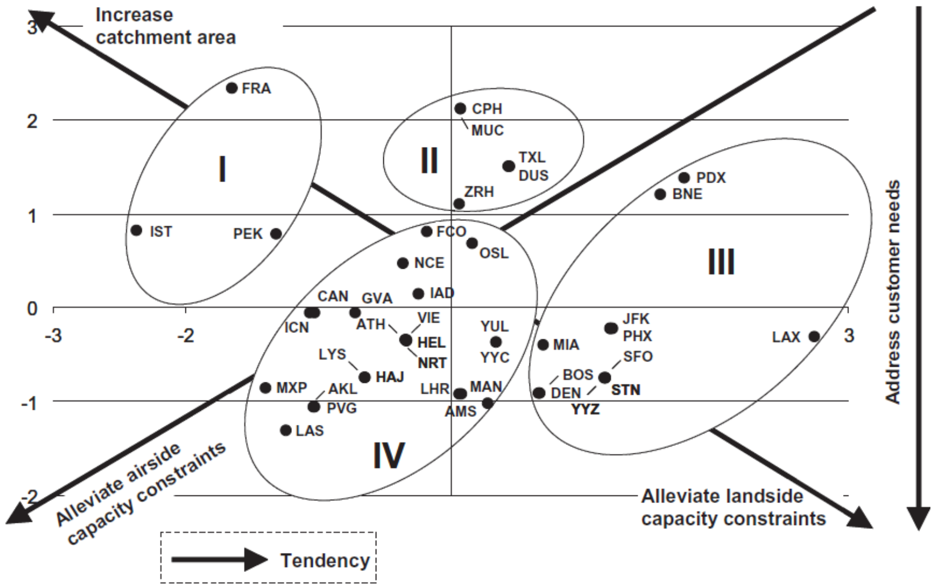


Figure 12 – Airport clusters based on motives for intermodal integration
Source: Vespermann and Wald (2011), p. 1193

Expansion of catchment area was studied by Widmer and Hidber (2001) as an *effect* of rail stations at airports. The authors conducted a Delphi questionnaire with a large and varied expert panel. At the time, a clear majority agreed that airport ground access by rail would extend the catchment area of any type of airport, especially in the case of high-speed rail, and that where different airports' catchment areas overlapped there would be opportunity for a more equal distribution of air passenger transport demand among those airports (Figure 13).

In what concerns the **intention to increase airside capacity** at the airport, several authors argue that air-rail intermodality, where rail can substitute short-haul feeder flights, may be a solution for freeing slots in airports. These free slots can then be used by long haul flights (Givoni and Banister, 2006) which compared to short haul feeder flights have higher landing fees, more passengers and are in general more profitable for the airport. This substitution is particularly popular at airports that need to respond to airside capacity restrictions, like scarce runway or gate capacity. Air-rail intermodality, in this case, alleviates airside congestion and enables airside volume growth within existing airport and terminal limitations (Vespermann and Wald, 2011).

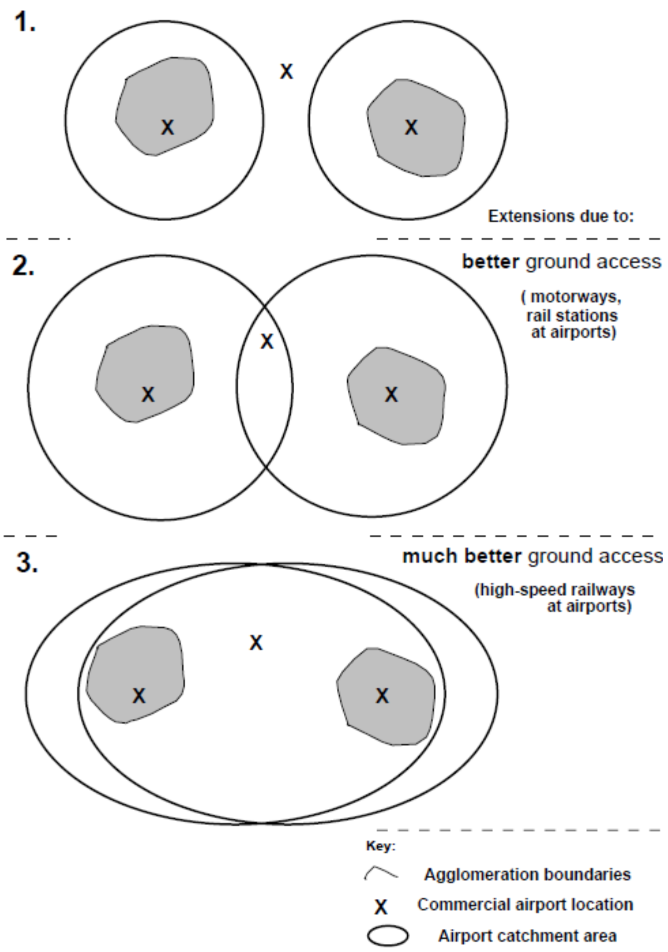


Figure 13 – Air passenger transport demand distribution between agglomerations
Source: Widmer and Hidber (2001), p. 6

Meeting customer needs for a seamless transport chain is an important driver associated with convenience, service quality and speed. Vespermann and Wald (2011) point out that airports may feel obliged to extend existing or establish new airport access opportunities in order to meet customers' increasing demand for less congestion and more reliability when accessing the airport.

Addressing environmental and landside congestion issues/targets by introducing intermodal alternatives is also an important driver for airports. Environmental impacts (air pollution, climate change and noise) are very critical today, as there are legal considerations, emission targets to be respected and costs associated with non-compliance. There are also image issues for the airport associated with environmental impacts (Eurocontrol, 2005b). In Givoni and Banister (2006)'s cost-benefit analysis of airline and railway integration on the Heathrow-Paris route, the environmental benefits are estimated to be significant – on one hand, NOx emissions were limited at Heathrow, so the estimated decrease in NO2 emissions represented savings and investment unblocking; on the other hand, private car trips as well as short-haul flights were expected to decrease by substitution. The evaluation showed a significant reduction in the effect on climate change and a less significant reduction in local air pollution. However, if freed slots are used for long-haul flights, this will lead to an increase in global environmental impacts for the airport (Givoni and Banister, 2006), although the large increase in capacity results in a lower impact per passenger, especially when opposed to other capacity increase solutions such as the expansion of runway capacity.

Air rail intermodality projects increase connectivity for airports, which in turn increases competitiveness against other airports (Givoni and Banister, 2006). Improved accessibility by public transport is a target for some airports, sometimes associated with landside congestion issues, including scarce parking possibilities and road congestion. There is some controversy about this driver though, and not all airports view this as motivation for intermodality, as parking revenues might decrease if private car trips to the airport are substituted by rail.

Airport managers consider 3 main barriers to air-rail integration (Eurocontrol, 2005b): car parking revenue loss, non-reallocation of released slots to new flights, overlap of airports catchment areas.

Car parking revenue loss, which we refer to as source of controversy in considering the driver for intermodality “improving landside congestion issues”, is one of the main concerns for airports, as parking fees represent a very important source of revenue. Improving accessibility by public transport entails the risk of a modal shift to public transport by private car users.

Non-reallocation of released slots to new flights is another risk, especially concerning airports which do not suffer from airside congestion. If some short-haul flights are substituted by rail and released slots cannot be sold, the airport will lose landing fees.

Expansion of catchment areas is viewed as a barrier in the sense that alongside increasing potential market it also promotes competition between airports when competitors’ **catchment areas overlap**. Eurocontrol (2005b) refers as an example that the future high speed line between Lisbon and Madrid should put Lisbon and Madrid airports in competition.

3.3 Airlines

In order to understand drivers and barriers for air-rail intermodality, we can distinguish 3 types of airline (IATA, 2003):

- **Network carriers** appear to selectively use air-rail intermodality to increase their competitive advantage against other airlines. Although they support the idea of a rail feeder service, substitution of their short-haul flights is not desired (rail feeders could reach destinations the airline doesn’t rather than substitute air feeder services already in place). The overall concept is however positive for all network airlines IATA (2003) interviewed.
- European **regional airlines** view high-speed rail as a competitor since a significant part of their market is feeding major air hubs. Although they do not directly object to air-rail intermodality, they state that as a competitor, rail is not on a level playing field with

them, as incentives and subsidies for the rail sector are significantly higher than comparable to benefits received by regional airlines.

- **Low cost carriers** in general don't provide connection services for passengers. Even on sequential flights on the same low cost carrier, passengers have to buy two separate tickets and transfer their own luggage, checking in twice. Therefore, air-rail intermodality **complexity and costs are not considered to be in accordance with the low cost model**. Although in the 2000 decade low cost carriers expressed little interest in air-rail intermodality other than the increase in airport ground accessibility, the business seems to be very dynamic and adaptable so the question is still uncertain (Eurocontrol, 2005b). IATA (2003) point out that eventually low cost carriers in Europe will face direct competition with high-speed rail although this hadn't started in 2003 at a major degree since high-speed rail corridors were very limited at the time.

From the above results, it is possible to identify the main drivers and barriers for airlines in general.

Airlines are motivated by the **possibility to efficiently substitute feeder flights by trains in order to free slots for more profitable routes**. This is true for airlines which operate hub and spoke networks on congested airports, where slots are scarce and expensive, so the way airlines use them makes a difference in terms of profitability (Eurocontrol, 2005b). Therefore, it is possible to free slots by replacing short-haul feeder flights, which are often not profitable on their own (although they can be, if considered as feeders for long-haul flights), by trains; those released slots can then be used for more profitable long haul flights.

Another driver for air-rail integration for airlines is the **reduction of operating costs** in order to increase profitability. As stated above, feeder flights are often not profitable on their own, but cannot be eliminated as that can mean losing market on long-haul flights when operating a hub and spoke network. Airlines are expected to incur operating costs following mode substitution, but this is expected to be more than compensated for by benefits of freed runway capacity and network economics (Givoni and Banister, 2006).

The most important barrier considered by airlines is the **loss of control of the feeder routes**. Airlines compete with rail operators on a number of trips, so it is only natural they be concerned to find themselves relying on their competitors to feed their hub. Also, there is a risk of losing passengers to other airlines that operate short-haul flights, as some passengers could still prefer to connect to a hub via short-haul flights. In view of this, many airlines maintain short-haul feeder flights on routes where they have made intermodal agreements, and in those cases, passengers will typically choose to fly to the hub if no incentive is given for intermodality.

Another important barrier for airlines is that intermodality will **benefit competing airlines** which operate point-to-point routes. One example is the agreement between American Airlines and SNCF. Air France will offer hub and spoke connections from many cities in France, to a hub and on to a North American destination. Thanks to their agreement with SNCF, passengers can choose to take a train to the hub and fly American Airlines instead.

The **cost of the intermodality project** is also viewed as a barrier for airlines, not in terms of funding the actual railway link necessary for the integration of air and rail but in terms of the investment for setting up integrated ticketing, luggage systems and check-in at railway stations. The airline must therefore expect benefits large enough to justify the investment required. At Frankfurt, for example, costs related to the automatic luggage system for the intermodal products were shared equally among Lufthansa, Fraport (the airport manager) and DB, the train operator (Eurocontrol, 2005b).

Airlines express concerns over the **difficulties selling the intermodal product** against air-air products. These concerns arise because on one hand intermodal trips are ranked low in booking systems and on the other hand passengers lack information on these products, and informing them represents marketing and advertising costs for the airline (Eurocontrol, 2005b).

3.4 Rail infrastructure companies

According to Eurocontrol (2005b)'s consultations with French and Portuguese railway infrastructure managers (RFF and REFER) and Portuguese high speed rail project managers (RAVE), rail infrastructure companies consider 4 main drivers for intermodality. Firstly, intermodality projects will require the **development/expansion of global rail capacity** associated with availability/increase of the number of train slots. Secondly, a better and ideally **optimal use of rail infrastructure** is to be expected in consequence of the increase in train frequencies to accommodate intermodal passengers, which motivates infrastructure managers since more trains represents more access fees from railway companies. Thirdly, air-rail intermodality projects **improve rail market share** as compared to other transport modes, making rail more attractive as an alternative. Finally, since air and rail infrastructure integration is presupposed, rail managers are motivated by **getting into a global transport network** and into a common environment with air transport. They expect to be able to articulate and coordinate with air transport in order to create excellent interconnectivity conditions.

Two main barriers were also mentioned in the above interviews, **funding** being the main one. Infrastructure costs for intermodal projects are very high, and even with public funding covering a part of the investment, rail infrastructure companies need to be sure profitability is good enough not to jeopardize their financial situation. Rail infrastructure operators are also concerned that improving access to the airport will **increase air transport competitiveness** as opposed to rail transport. Eurocontrol (2005b) illustrates this barrier with the case of Paris-CDG airport, which was still not connected to the city centre by high-speed rail because SNCF, the rail operator, was not interested in improving the attractiveness of Air France since they are their competitors.

3.5 Rail operators

According to Eurocontrol (2005b)'s consultations with Thalys International (which operates a high-speed rail service network in France, Belgium, the Netherlands, Germany), rail operators consider 4 main drivers for intermodality. **Increasing the market share** of the rail operator is the main driver. Operators consider factors like the existence of heavy demand between the airport and the destinations their rail service would reach, the ability to attract passengers from road modes, the prospect of the development of agreements with as many airlines as possible for the transport of passengers from other cities, capturing short-haul air passengers by substitution and also exclusivity of operation. In fact, IATA (2003) states that intermodality is a way to maximize the number of passengers on trains, without any significant marginal costs other than usual operating costs, if the rail infrastructure is in place. Also, intermodality projects could, in the operators' view, **improve the image of high-speed rail**. Selling through air channels can capture passengers who are unaware of high-speed rail alternatives – IATA (2003) argue that intermodality in this case plays a showcase role.

Barriers considered by rail operators include, again, the **financial issue** – benefit/cost ratios may not justify investment costs. Furthermore low cost carriers often offer lower prices than private rail operators can for high-speed rail routes, which means modal competition is fierce. In this regard, Eurocontrol (2005b) mentions that rail operators doubted that agreements with airlines for full short-haul flight substitution would occur, since airlines also compete among each other. As well as the rail infrastructure operators, rail service operators are concerned that improving access to the airport will **increase air transport competitiveness** as opposed to rail transport. One final barrier for rail operators is **capacity** – if train slots and platform capacity are not enough to guarantee feeding of the airlines' hubs, intermodal agreements will not be easy to comply with. Eurocontrol (2005b) illustrates this issue with a situation where Thalys had to consider the use of duplex carriages to increase train capacity due to scarcity of train slots.

4 Air-rail intermodality infrastructure, products and success factors

4.1 Railway stations at airports

Based on criteria such as travel distance or speed, we can identify several types of airport rail links. In fact, there are airport rail links which allow long distance travel to another country, and others which simply connect the airport to the city center; some may be part of the urban/suburban rail network, some may be integrated in the national network; others may not have any connection with them. It is important to classify and distinguish the links because those differences may generate different effects on the intermodal operation at the airports where they are located.

Major European airports are within or near urban areas where we can find implemented and expanding rail networks of several types – urban, suburban and interurban (EC, 1998). The initial purpose of railway stations at airports was to ease road congestion between the city centre and the airport. The initial concept developed towards the integration of airport rail stations in the national rail networks – urban, suburban, national and, since 1994, high-speed rail networks.

EC (1998) illustrates the extreme cases of airport rail links with regard to their integration in the rail network – the central rail station of the city as a railway hub, in which case air passengers must first connect to that station and then change trains to continue their journey; the airport rail station as a railway hub, in which case the air passengers may continue their journey off the flight for a large number of destinations, catching only one train. These cases are illustrated in Figure 14.

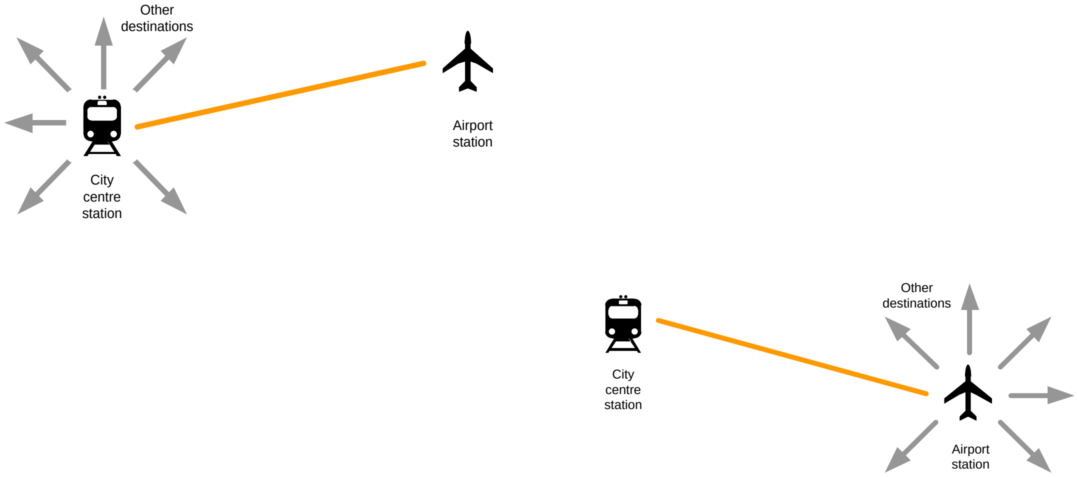


Figure 14 – Extreme cases of airport rail station integration on the railway network

Source: Adapted from EC (1998), p. 258

The following subchapter describes the criteria used in the literature and the categories resulting thereof, discusses the types of rail links adopted in this study and selects categories that will be relevant to this study. It is followed by an inventory of significant air-rail links.

4.1.1 Types of air-rail links

In most cases, applicable literature categorizes airport rail links based on one or two of three criteria:

- *Service range*: common to most authors, *service range* distinguishes between airport-to-city-centre links, links which integrate airports into the national rail network, connections to the metro or suburban rail network and connections to international high-speed networks.

- *Service type*: also widely used for sorting airport rail links; for national service ranges, for example, it makes it possible to distinguish between intercity, regional or high-speed services (some authors will only distinguish conventional from high-speed services).
- *Link design:* describes the airport rail link configuration and makes it possible to distinguish between dedicated lines, metro links and branch or spur lines on the national network.

Within service range, the category "links to another airport" was created separately by EC (1998) with the aim of studying the potential redistribution of traffic between airports in scenarios of major air congestion.

It is relevant to mention that Eurostat has a classification of airport connections to other modes of transport, apparently based on service type (high speed rail, main line rail, metro). Eurostat's data series on European airports' connections to other modes of transport starts in 2003 and is updated yearly. However, the database has very little available data.

Link design categories proposed by Stubbs & Jegede (1999) are illustrated on Figure 15.

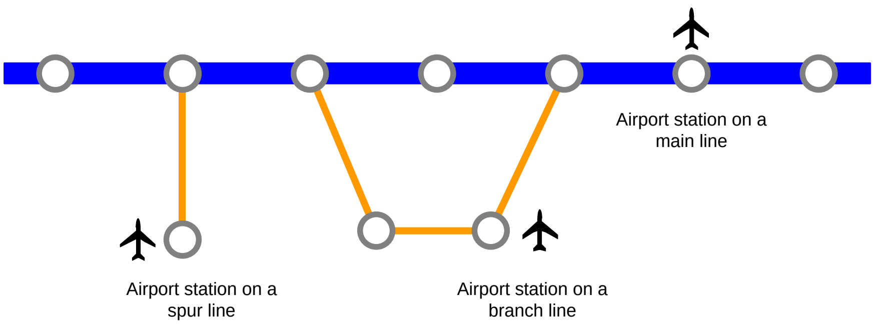


Figure 15 – Types of airport rail links to the national railway network, according to Stubbs & Jegede (1998)

Table 2 summarizes the literature we have analyzed, sorting it by criteria used. As was described earlier, service range and service type are widely used. The tables that follow summarize the categories assigned to each criterion by these studies. For service range (Table 3, which is adopted by 58% of authors, the most common distinction made by authors is the one between city-centre links and national links which integrate the airport in the railway system and make it possible to reach national/international destinations. For service type (Table 4), which is adopted by 67% of authors, all authors use high-speed services as a category; distinction of conventional services or consideration of different types of rail modes such as light rail and metro varies, but mostly long-distance services, be it regional or intercity, are separated from local or urban services such as metro. For link design (Table 5), which is adopted by 25% of authors, all authors consider main line links, where the airport station is fully integrated in the national railway system; one or more categories are used for branch lines off the main railway line and special dedicated lines are generally separated from others.

Author	Criteria		
	Service range	***Service type***	***Link design***
Stubbs & Jegede (1998)	•		•
ATAG et al. (1998)			•
EC (1998)	•	•	
Widmer & Hidber (2000)	•	•	
Janić & Reggiani (2001)	•	•	
Duff (2002)		•	
López Pita (2003)			•
Eurocontrol (2004a)	•	•	
Eichinger (2007)	•	•	
Givoni & Banister (2007)	•		
Kouwenhoven (2008)		•	
Eurostat		•	
% of authors adopting the criterion	*58%*	*67%*	*25%*

• Criterion is adopted by the author | (empty) Criterion is not adopted by the author

Table 2 –Summary of criteria for classifying airport rail links

Author	Service range categories					
	City-centre	Urban / Metro	Regional	National	Other airport	International (1)
Stubbs & Jegede (1998)	•	•		•		
EC (1998)	•			•	•	
Widmer & Hidber (2000)	•			•	•	
Janić & Reggiani (2001)	•			•	•	
Eurocontrol (2004a)	•			•		
Eichinger (2007)	•		•	•		
Givoni & Banister (2007)	•	•	•	•		•

(1) Integrated with the *national* category

• Category is adopted by the author | (empty) Category is not adopted by the author

Table 3 –Summary of service range categories for classifying airport rail links

Author	Service type categories						
	Dedicated	Light-rail / tram	Metro	Local / suburban	Long-distance conventional (1)	Conventional (2)	High-speed
EC (1998)						•	•
Widmer & Hidber (2000)						•	•
Janić & Reggiani (2001)		•	•	•	•		•

Author	Service type categories						
	Dedicated	Light-rail / tram	Metro	Local / suburban	Long-distance conventional (1)	Conventional (2)	High-speed
Duff (2002)		•	•	•	•		•
Eurocontrol (2004a)	•	•	•	•	• (3)		•
Eichinger (2007)		•	•	•	•		•
Kouwenhoven (2008)	•		•		• (3)		
Eurostat			•		•		•

(1) Includes intercity and interregional categories
(2) Used by authors who consider only two categories - high-speed opposed to conventional
(3) The study refers to these trains as regional services.

•	Category is adopted by the author		Category is not adopted by the author

Table 4 –Summary of service type categories for classifying airport rail links

Author	Link design categories					
	Dedicated line	Metro	Spur line	Branch line	Main line	Accidental link (1)
Stubbs & Jegede (1998)	•	•	•	•	•	
ATAG et al. (1998)	•	•			• (2)	•
López Pita (2003)(3)				•	•	

(1) Accidental links as introduced by ATAG et al. (1998), are the cases where an airport is close enough to the railway to have a station built, not necessarily on the airport, but close enough to serve it. These links are built as a consequence of the convenience (accidental or as a result of some degree of planning) of an airport's location in relation to the railway line.
(2) This study further splits main line links into high-speed main line and conventional main line
(3) This study looks only into high-speed links.

•	Category is adopted by the author		Category is not adopted by the author

Table 5 –Summary of link design categories for classifying airport rail links

Our present goal is to assess the factors of air-rail intermodality, and it is likely that each type of airport rail link will impact the passenger option for intermodal travel differently. Therefore, we will choose a categorization that is suitable for this study and select only the links which are relevant for the type of intermodal travel we are analyzing. That is, those links which make it possible for rail to replace feeder flights and / or significantly increase the catchment area of an airport. Consequently, links whose sole purposes are access to the city or metropolitan area where an airport is located are excluded from this study.

In order to make this distinction, we will use as a relevant attribute the service range. Authors that look specifically into the effects of railway stations at airports – EC (1998) and Widmer & Hidber (2000) – use service range and type to classify airport rail links, but within the links which integrate the airport in the national railway network they oppose only high-speed to (all) conventional services. Thus, these studies do not distinguish those links which provide local or suburban services from those which provide conventional long-range services such as intercity trains. As previously stated, that distinction is a very relevant one for this study, therefore, alongside service range, we will consider service type, developing the categories further than high-speed and conventional trains so that we can clearly distinguish intercity trains from suburban services.

The aforementioned studies about the effects of railway stations at airports consider *other airports* as a service range category. Although the specificity of the effects of these connections justifies its separate category, there are scenarios in which they can be studied as conventional or high-speed intercity connections. In fact, a station at an airport typically has good accessibility to the metropolitan area it serves and can be used by non-air passengers, who do not wish to proceed by air. As this work does not intend to explore the specificity of these links, they will be included in the category corresponding to their type of service (long-range conventional or high-speed).

Finally, although link design may be relevant for the seamlessness of an intermodal journey, we will keep our classification simple by using only two attributes: the most widely used ones as well as the simplest to combine.

Service range	Service type	Definition	Example
City / Urban	Dedicated airport to city-centre line	Dedicated rail service directly from a city-centre to the airport, without needing to change trains, mostly without intermediate stops.	Stockholm-Arlanda (ARN): Arlanda Express
	Metro	Urban public transport service provided by metro, with a station at the airport.	London-Heathrow (LHR): London Underground's Piccadilly Line
	Light rail / tram	Urban public service provided by light rail or tram, with a stop at the airport	London-City (LCY): Docklands Light Railway
National railway network	Local / suburban trains	Public transport service provided by local or suburban trains with a station at the airport	Stockholm-Arlanda (ARN): Upptåget service
	Long-distance conventional	Long-distance transport service provided by conventional trains with a station at the airport	Zurich (ZRH): InteRegio and Intercity services by SBB-CFF-FFS
	High-speed trains	Long-distance transport service provided by high-speed trains with a station at the airport	Paris-CDG (CDG): Ligne Grande Vitesse Interconnexion Est

Table 6 – Categorization of airport rail links adopted in this study

4.1.2 Inventory of relevant European air-rail links

This inventory of European air-rail links was compiled from the literature review which was carried out for the previous subchapter and from railway company and airport websites[2]. Only the categories relevant to this study were listed – long-distance conventional and high-speed services which integrate the airport in national/international rail networks.

Before limiting our view into Europe, it is relevant to start by comparing the situation between continents. As shown in Table 7, European airports have been investing in airport rail links and plan to keep building them – 64% of European airports in the top 150 airports by passenger numbers already have a link and 9% more are actively pursuing one; Asia also displays investment in this area – 40% of top airports have rail links and 23% more are planning a rail connection; in North America, by contrast, only 22% of top airports have rail links (data from Kouwenhoven, 2008, including metro and dedicated city-centre links).

Continent	Existing air-rail links	Proposed air-rail links	Number of airports in the top 150
Africa	0	0	2
Asia	14	8	35
Europe	29	4	45
North America	12	6	59
South America	0	0	4
Oceania	2	0	5

Table 7 – Existing and proposed air-rail links (2006) considering top 150 airports by passenger numbers
Source: Adapted from Kouwenhoven (2008), p. 16

For the following list of European airport rail links, current (as of August 2012) operators were also added.

Service range	Service type	Airport	Rail operators
National railway network	Long-distance conventional	Amsterdam-Schiphol (AMS)	DB Fernverkehr NS HighSpeed NS
		Birmingham (BHX)	Arriva Trains Wales CrossCountry London Midland Virgin Trains
		Brussels (BRU)	NMBS/SNCB
		Budapest (BUD)	MÁV
		Cologne/Bonn (CGN)	DB
		Copenhagen Kastrup (CPH)	DSB DSB First
		Düsseldorf (DUS)	DB

[2] Websites are listed on a separate section of the bibliography.

Service range	Service type	Airport	Rail operators
		Frankfurt (FRA)	DB
		Friedrichshafen (FDH)	DB
		Geneva (GVA)	SBB-CFF-FFS
		Glasgow-Prestwick (PIK)	First ScotRail
		Leipzig/Halle (LEJ)	DB
		London-Gatwick (LGW)	Southern First Capital Connect First Great Western
		London-Luton (LTN)	East Midlands Trains First Capital Connect
		London-Stansted (STN)	Greater Anglia CrossCountry
		London-Southend (SEN)	Greater Anglia
		Lübeck Blankensee (LBC)	DB
		Manchester (MAN)	First Transpennine Express Northen Rail Arriva Trains Wales
		Milan-Malpensa (MXP)	Trenitalia
		Oslo-Gardermoen (OSL)	NSB
		Paris-CDG (CDG)	SNCF
		Pisa Galileo Galilei (PSA)	Trenitalia
		Rome Leonardo da Vinci-Fiumicino (FCO)	Trenitalia
		Southampton (SOU)	CrossCountry South West Trains Southern
		Stockholm-Arlanda (ARN)	SJ UL
		Trondheim (TRD)	NSB
		Zurich (ZRH)	SBB-CFF-FFS
	High-speed trains	Amsterdam-Schiphol (AMS)	NS HighSpeed Thalys
		Brussels (BRU)	Thalys
		Cologne/Bonn (CGN)	DB (ICE)
		Copenhagen Kastrup (CPH)	SJ
		Düsseldorf (DUS)	DB (ICE) Thalys
		Frankfurt (FRA)	DB (ICE)
		Leipzig/Halle (LEJ)	DB (ICE)
		Lyon-Saint Exupéry (LYS)	SNCF (TGV)
		Paris-CDG (CDG)	SNCF (TGV)

Table 8 – Existing European long-distance air-rail links and operators (2012)

Source: Operator and airport websites

4.2 Air-rail products in Europe

It is possible to list a number of successful air-rail intermodal products in Europe which are the result of operator agreements – airlines and rail operators. Table 9 describes some of these products generally.

Product name	Operators	Description
TGV Air	SNCF Air France About 10 more airlines	TGVAir is a code-sharing agreement between SNCF and Air France plus a few other airlines for passengers traveling through Paris-CDG, and proceeding to several French cities by high-speed rail. It has an integrated ticket and end-to-end check-in at the railway station with a 15 minute deadline. Travel documents for the trip need to be picked up at TGVAir counters available at rail stations and at Paris-CDG airport. No baggage handling is available for the train-leg or transfer. To check baggage in, passengers can to go to their flights' check-in counters, but an e-services baggage drop-off counter is also available for this product. Extra frequent flyer miles are awarded for TGVAir trips. There is some degree of schedule coordination for this product. This product is also available for passengers flying though Paris-Orly. Passengers are transferred to the rail station at Paris-CGD by private shuttle. It is possible to buy TGVAir tickets online through operator websites.
Rail & Fly	DB About 70 airlines	Rail&Fly is a train ticket option offered by airlines and tour operators in combination with an air ticket or package tour, at a discount price or, in some cases, included in the airfare. The train ticket can be used the day of the air trip and the next (or previous, if the air trip is a departure). It is valid for all DB trains, except auto trains, special trains and night trains. The ticket can only be used for the ICE Sprinter if seat reservation is made and paid for in advance. Little integration exists, and even if the product stands on common distribution, this ticketing option is scarcely available via internet booking engines. No baggage handling service is offered and it isn't possible to collect frequent flyer miles with this ticket. However, low operational complexity and good discounts make this product attractive for both passengers and operators. Other strong points of this service are that it is offered by a large number of airlines, including low-cost carriers, and that all rail destinations within the DB network are possible.
AiRail	DB Lufthansa Fraport	AiRail is a joint venture of Lufthansa, DB and Fraport between Frankfurt and Stuttgart and between Frankfurt and Cologne. It is a code-sharing agreement which allows Lufthansa the use of a flexible number of carriages or set sectors at the hourly DB trains that run from Frankfurt Airport rail station into Cologne and Stuttgart. A good level of schedule coordination exists for this product. This service is associated with considerable investment and operational costs, as it started out offering baggage handling and end to end check-in at rail stations, which meant the installation of check-in facilities, baggage handling, security screening and customs offices at railway stations, adding modified baggage carriages to trains and having personnel operate and manage these operations. Baggage handling is no longer provided, because not only did it represent an extra cost, it impacted on train station operations and caused train delays on DB's highly synchronized network due to baggage loading. Part of the investment was for extending the baggage handling system of Frankfurt Airport into the train station. At the present time, AiRail passengers can still benefit from this investment, since they can check-in our pick-up baggage at the airport train station. AiRail products allow passengers to earn frequent flyer miles with Lufthansa

Product name	Operators	Description
		and integrated tickets can be bought online from operators. Over 20 other airlines, some outside the Star Alliance, can use the AiRail service, but Lufthansa and DB remain single operators. Because the AiRail product is does not strictly comply with standard security procedures in international aviation, interested airlines have to apply for approval at their home country's civil aviation authority. Train on-board service is comparable to service offered on European short-haul flights.
Flugzug Basel	SBB-CFF-FFS Swiss	Flugzug Basel is a feeder service between Basel Central Station and Zurich Airport resulting from a code-sharing agreement between Swiss and SCC-CFF-FFS. This product has integrated ticketing. Common online booking is available from SWISS. This service also offers end to end check-in at the entry rail station, but at an additional cost. Baggage handling is also offered at an additional cost. Other rail destinations are available, as long as they connect via Zurich. However, direct links are only offered for Basel. It is possible to earn frequent flyer miles from this service. A frequency of 17 daily connections both directions allows for low connecting times.
Fly Rail Baggage	SBB-CFF-FFS Swiss	Although this product isn't a passenger intermodal service, it is one that facilitates passenger air-rail intermodality. Fly Rail Baggage advertises a product that allows passengers to send their luggage from any airport in the world to their rail station destination in Switzerland via Zurich or Geneva airport, regardless of their choice of airline for arriving in Switzerland. Passengers check-in their luggage and customs declaration at a Swiss representative or at the railway station, on the opposite trip.

Table 9 – Selected intermodal air-rail products in Europe
Source: Operator websites, Eichinger (2007) and Grimme (2007)

There are many other agreements between operators in Europe which result in different products with varying degrees of seamlessness. Code-sharing agreements allow trains to be assigned airplane codes and be sold through computer reservation systems. Many non-European airlines flying into Europe have code-sharing agreements for their intercontinental flights.

Two other specific products are worth mentioning, although not enough information was gathered about them to include them in the present analysis. The first is the outcome of an agreement between Air France and Thalys according to which the former stopped operating flights between Paris-CDG and Brussels and the latter reserved at least one carriage for Air France passengers on the Paris-CDG-Brussels route and increased its train frequencies. This product offers integrated ticketing, online booking and end to end check-in at the Brussels station. Baggage is weighted and labeled in Brussels and transported on the train in a special compartment, but it needs to be carried by the passengers between the train and the airport and passengers who wish to check it in for the aircraft hold need to do it at their flights' check-in counters. At least two other operators have agreements with Thalys for the Brussels-Paris-CGD feeder train.

The second product – referred to by Eichinger (2007) as Night and flight – is an interesting one as it offers the combination of a one-way night train (operated by City Nightline) with a one-way flight back by SWISS. It is a highly segmented product, its target being business passengers with early morning or late evening appointments. It grants far-reaching flexibility, as there are no restrictions as to the length of stay and it is even possible to start the return journey from a different city. Also, there is integrated ticketing. Wake-up service and breakfast on the night train are included.

The main features of the selected intermodal products are summed up in Table 10. TGVAir and AIRail are full featured intermodal products which were built specifically to attract air-air travelers, potentially allowing the substitution of feeder flights to major hubs Paris-CDG and Frankfurt. It is interesting to notice that even these products are not able to offer through baggage handling. AIRail's system was in place for some years at the cost of significant investment, but it was eventually discontinued for operational and security issues. In this way, from this group of products, the successful baggage handler is a separate product which is not concerned with the transport of the baggage *owners* – Fly Rail Baggage. The passenger might even fly on the same airplane as the baggage, but baggage is handled as cargo or mail from origin to destination. Flugzug Basel will handle baggage, but this is not as a feature of its product package, rather as an additional service at an extra cost.

	Intermodal air-rail products				
Main features	**TGVAir**	**Rail&Fly**	**Flugzug**	**FlyRailBaggage[8]**	**AIRail**
Integrated ticketing	•		•	•	•
Common online ticket distribution	•	• [1]	•		•
Baggage handling			[2]	•	
Schedule coordination	•		• [3]		•
End to end check-in	•		[2]		•
"Airplane grade" train on-board service	•				•
Frequent flyer miles	•		•		•
Delay/connection assistance	•		•		•
High number of possible destinations	• [4]	•	•	• [5]	
Booking flexibility		• [6]		• [7]	

[1] Available only in very few cases.
[2] Available at an additional cost.
[3] Although no schedule coordination is advertised by the operators, high frequencies allow for short connection times.
[4] 20 rail destinations potentially available, but that number depends on the specific airline agreement; Air France, for example, offers 9 possible rail destinations by TGVAir.
[5] Advertised to be available from all airports in the world.
[6] Within a day of the air trip, all partner trains are available with very few exceptions.
[7] Within a day of arrival, baggage will be stored for free at the rail station; after that a storage fee is charged.
[8] Some of the features don't apply, as this service carries baggage, not passengers.

•	Product has the feature		Product does not have the feature

Table 10 – Summary of main features of intermodal products in Europe

4.3 Measuring the success of air rail intermodality

Measuring intermodality is a difficult task, mostly due to current national and European statistic frameworks. While the measurement of intermodality and the development of indicators are beyond the scope of this study, it seems relevant to know how the success of air-rail integration is assessed when trying to understand the factors that determine it.

Indicators are associated with evaluation, which of course depends on targets/goals, therefore our references are European studies developed within EU policy frameworks.

A large proportion of relevant research has focused on transfer points and looks into supply rather than demand. Two main indicators have been used to quantify barriers to intermodality: travel time and travel cost. Both indicators are often embedded in evaluative research and with a qualitative approach. One example is the GUIDE project (EC, 1999), which focused on urban public transport and asked transport users, employees and operators about their perceived importance of 66 criteria, having obtained a performance gap for intermodality at ten interchanges. For characterizing transfers in intermodal journeys, the most widely used indicator is the distance between modes (Tapiador et al., 2009). *MODAIR: Measurement of inter-modality at airports* (Eurocontrol, 2005a) built indicators of airport intermodality and distinguished those related to airport access (type 1 intermodality) from those related to airport integration in rail networks (type 2 intermodality). This project also separates supply from demand indicators. Project *KITE: a knowledge base for intermodal passenger travel in Europe* (KITE, 2009a), on the other hand, was interested in indicators for cost-benefit analysis of intermodality projects. Distinction was not made between types of intermodality, but focus was also on the main transfer node. With those two references, it is possible to present a straightforward list of indicators grouped into four categories (Table 11):

- Indicators of intermodal infrastructure
- Indicators of intermodal operators
- Indicators of intermodal services
- Indicators of intermodal demand

Category	Objective	Indicator
Infrastructure	Existence of rail infrastructure in the airport area	Number of rail infrastructures connected to the airport(1)
	Access time between the intermodal infrastructure and the terminal	Minimum connection time Path effort grade Usage level of waiting time Waiting conditions and service facilities
	Rail capacity	Yearly capacity in number of passengers(2) of the railway stations located in the airport area
	Interest of intermodal infrastructure for airport users	Number of cities that are served by train from the airport for a train journey time not exceeding 3 hours
Operators	Number of intermodal operators	Number of intermodal air operators
		Number of intermodal rail operators
		Number of non-European airlines proposing intermodal service

Category	Objective	Indicator
	Market share	Yearly ASKs[3] of airlines having intermodal agreements, over the total number of ASKs at the airport
Services	Existence of intermodal agreements	Number of intermodal agreements
	Specificities of intermodal agreements	Number of characteristics of each agreement weighted by the yearly market share in ASKs of the airline operator summed up over all agreements
	Intermodal air supply	Number of intermodal destinations by air relative to the total number of destinations
		Number of daily air frequencies summed up over all intermodal destinations
	Intermodal rail supply	Number of intermodal rail destinations
		Number of daily rail frequencies summed up over all intermodal rail destinations
		Number of destinations offered by rail in the scope of an intermodal agreement where there is also a service by air
	Competition between air and rail	Number of daily frequencies by air on all competing routes, divided by the total number of daily frequencies (air+rail)
Demand	Number of intermodal passengers transported	Number of passengers using intermodal services relative to the number of passengers flying to or from the airport on flights where intermodal agreements exist
	Number of multimodal passengers transported	Number of passengers using successively rail and air (whether they benefit from an intermodal agreement of not) relative to the number of passengers flying to or from the airport on flights where intermodal agreements exist
	Potential demand for intermodal service with current service levels	Population of the destination cities directly served by train from the airport, weighted by the percentage of the population of the country that travels yearly by air multiplied by the average number of trips each person makes
	Potential demand for intermodal service on existing network	Population of all the rail destination cities that could be directly linked to the airport in a journey time inferior to 3 hours weighted by the percentage of the population of the country that travels yearly multiplied by the average number of trips each person makes

(1) Eurocontrol (2005a) refers to the number of rail stations at the airport; it also seems relevant to consider other aspects of the rail infrastructure such as the number of railway lines on airport rail station.

(2) Eurocontrol (2005a) refers to the number of passengers; it also seems relevant to consider seats as a measure of capacity.

(3) ASK: Available seat kilometer

Table 11 – Airport intermodality indicators

Source: Adapted from Eurocontrol (2005a), pp. V-VI and KITE (2009a), pp. 24-26

The indicators above can be summed up into macro-level indicators for airport integration which allow for an overview of an airport's current intermodality situation (Eurocontrol, 2005a) and also its potential one, if prediction models are able to estimate the variables needed (Table 12).

Category	Objective	Indicator
Supply	Infrastructure	Number of rail infrastructures connected to the airport
	Operators	Yearly ASKs of airlines having intermodal agreements, over the total number of ASKs at the airport
	Service	Number of intermodal destinations by air relative to the total number of destinations
		Number of intermodal destinations by rail
Demand	Demand	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit

Table 12 – Macro level indicators for airport integration

Source: Adapted from Eurocontrol (2005a), p. VIII

In summary, European research has shown that success for air-rail intermodality can be evaluated in a CBA framework which assesses projects' social and economic benefits. Additionally, major indicators of success, according to literature, are:

- High passenger demand
- Large number of intermodal service destinations (by air and rail)
- Infrastructure integration
- Existence of intermodal agreements

4.4 Factors of air-rail intermodality

We set out to define the success factors for air-rail intermodality. The main difficulty of this task lies in the large number of factors impacting on the development of intermodality and in their complex interrelationships.

After a summary review of relevant literature, we will discuss factors and attempt to associate them with the actors in air-rail intermodality discussed in chapter 3 and the domains of intermodality success discussed above.

4.4.1 Literature

Different authors set out to determine the factors of intermodality with different formulations and purposes. A simple description of each study's main goals and formulations of the factors of intermodality, as well as the methods used to determine them and particular air-rail links studied is given on Table 13.

Project / Paper	Formulation	Methods	Specific air-rail links or airports studied
ATAG et al. (1998)	Providing guidance for successful air-rail links	Expert panels	
Stubbs and Jegede (1998)	Requirements for air-rail integration	Case studies	Airports in England, Wales and Scotland
IATA (2003)	What are the barriers that are	Among others, the	Montréal-Frankfurt-

Project / Paper	Formulation	Methods	Specific air-rail links or airports studied
	perceived to rail/ air intermodal development? What solutions exist, or could be developed to resolve such problems?	most relevant for this study are: Customer Survey Case studies based on sample journeys carried out by the research team Operator interviews	Stuttgart London-Paris-Marseille Brussels-Amsterdam-Other Brussels-Paris-Other London-Madrid-Seville
Chi and Crozet (2004)	In air-rail intermodality, what makes the case of Paris-CDG successful and the case of Lyon Saint-Exupéry not so successful?	Case study	Paris-CDG airport Lyon Saint-Exupéry airport
Cokasova (2006)	What are current passenger needs concerning intermodal transport shift? Based on what criteria do passengers choose each transport mode? What is passengers' ranking of travel factors? What is the importance that passengers attach to travel attributes? What are the commonalities between business and leisure passengers, male and female, frequent and not frequent passengers?	Among others, the most relevant for this study is: Passenger survey	Lisbon airport Paris CDG airport Paris-Brussels-Amsterdam (Thalys) London-Paris (Eurostar)
EC (2006b)	To investigate the factors determining air and rail market share	Case studies	8 European air links with rail competitors (based on London, Madrid, Paris, Frankfurt and Rome)
Eichinger (2007) and Eichinger and Knorr (2004)	Characteristics of German air–rail link offers and discussion of their competitive implications Critical success-factors of air-rail links	Case studies	German air-rail products
Grimme (2007)	General prerequisites for market success of intermodal services	Case studies	German air-rail products
KITE (2009b)	To deliver guidelines for seamless intermodal interchanges	Operator survey Case studies	
LINK (2009)	To deliver recommendations for solutions to the key issues in passenger intermodality: passenger information and ticketing, networks and interchanges, integration of the last urban mile, planning and implementation and context conditions for intermodality	Stakeholder survey	
HERMES (2010)	To identify and develop prototypes of suitable business models for intermodal or interconnecting services for short distance/long distance intermodality	Stakeholder consultation Case studies	
Janić (2011)	Pre-conditions which relate to removing or substantially mitigating		London-Heathrow

Project / Paper	Formulation	Methods	Specific air-rail links or airports studied
	existing barriers in order to implement high-speed rail substitution at a given airport. Factors are assumptions of the author's estimation model for the effects of substituting some short-haul flights with high-speed rail		
Vespermann and Wald (2011)	Assessing an intermodal best practice solution for the integration of air and rail	Case study Expert interview	Frankfurt airport
AEROAVE (2011)	Elements needed for the development of air-rail intermodality Aspects most valued by passengers in air-rail products	Case studies Expert panels Passenger surveys Cost-benefit analysis	Madrid-Barcelona Madrid-Toledo Málaga Airport

Table 13 – Literature on factors of intermodality

Some studies classify factors into categories, others simply list them. Not much importance was given to the way factors are classified in current literature since not as many studies as was expected do it, and where classification was identified, the criteria were varied and not always clear. However, it was necessary to group factors, as many studies use very similar factors which are variations or specifications of each other. Still, most variations were listed. Table 14 identifies these factors, which are discussed in the following subchapters. Table 15 relates factors with the projects/papers which consider them.

Groups	Factors
Ease of access/egress	Rail station accessibility Parking availability at rail station Baggage trolleys and ramps at the rail station Airport accessibility
Ease of transfer at airport (physical)	Infrastructure integration Connection distance between airport rail station and air terminal Connection walking distance between airport rail station and air terminal Number of level gaps in the walking transfer between airport rail station and air terminal (stairs, ramps, escalators, lifts) Design adaptation for disabled passengers making the transfer between airport rail station and air terminal Other comfort issues in the transfer path – weather protection, lighting, cleanliness, corridor design, seating availability, good supply of shops and facilities General perception of security on the transfer path at the airport
Ease of transfer at airport (logical)	Real time information on board the train and aircraft, at railway station and at airport Signposting Rail carriage identification Identification of staff Personalized information services (by mobile phone) Information language Identification of information desk
Ease of transfer at airport (baggage and check-in)	Baggage handling Check-in available at rail station (end to end check-in)

Groups	Factors
Travel time	Overall travel time Rail leg travel time Transfer time Schedule coordination for optimization of transfer time Access/egress time Generalized travel cost (also included in the ticket price group)
Frequency, schedule and capacity	Intermodal product frequency Rail link frequency Air link frequency Rail capacity
Reliability and punctuality	Reliability Punctuality
Delay assistance	Operator agreements for lost connections due to delays Single contact for responsibility and delay assistance Real time information on alternatives in case of contingencies
Connection opportunities and passenger volumes	Number of destinations covered directly by rail Number of transfers needed in the rail leg of the journey Passenger volume at the airport Availability of intercontinental long-haul air services at the airport
Mode preference	Cultural/personal mode preference for rail or air
Ticket price	Ticket price Generalized travel cost (also included in the travel time group)
Rail on-board comfort and customer service	General seating comfort (seat, table, hand baggage, leg room) Steward at train carriage Additional services: plug-in sockets, seat catering, newspapers, wifi, movies Sleeping compartment option
Passenger incentives	Discounts and season tickets Frequent flyer miles obtained from rail legs
Flexibility	Open tickets for rail leg Refundable tickets
Security	Passenger screening at train station check-in Train platform access reserved for train ticket holders
Integrated ticketing	Integrated ticketing (rail and air legs) Common booking/reservation (for rail and air legs) Compatibility of boarding pass and train reservation systems Common ticket sale (for rail and air legs), even when integrated ticketing is not available
Marketing	Product awareness Internet distribution (to sell or book journeys) Display rank at computer reservation systems Product positioning Quality standards, benchmarking and feedback management
Governance	Existence of an intermodal manager Funding Ticket revenue sharing settlement Data sharing between operators Cooperation between the various actors
Legal and regulatory	Complexity of the legal framework Market (de)regulation Level of integration in planning Planning times Complexity of technical standards Common guidelines for information Articulation with urban planning Intermodality facilitation strategies

Table 14 – Factors for intermodality

Project / Paper	Access/egress	Transfer (physical)	Transfer (logical)	Transfer (bag.& check-in)	Travel time	Frequency, schedule, capacity	Reliability and punctuality	Delay assistance	Connections and pass. volume	Mode preference	Ticket price	Rail comfort &customer service	Passenger incentives	Flexibility	Security	Integrated ticketing	Marketing	Governance	Legal and regulatory
ATAG et al. (1998)		•	•	•	•		•	•	•		•	•	•		•	•	•	•	
Stubbs & Jegede (1998)	•	•	•	•	•	•			•							•			
IATA (2003)		•	•	•	•	•	•	•		•	•	•			•	•	•		
Chi and Crozet (2004)						•			•							•	•		
Cokasova (2006)	•	•		•	•	•	•				•	•		•					
EC (2006b)	•				•	•	•				•	•							
Eichinger (2007) & Eich. & Knorr (2004)				•	•	•		•	•			•	•	•		•			
KITE (2009b)	•	•	•	•	•				•							•		•	•
LINK (2009)												•				•	•	•	
HERMES-D1 (2010)		•	•		•											•	•	•	•
Janić (2011)		•	•	•	•	•					•								
Grimme (2007)		•		•	•	•			•	•			•		•	•	•		•
Vespermann and Wald (2011)		•		•		•			•							•			
AEROAVE-D4 (2011)	•	•	•	•	•			•	•		•	•	•		•	•	•		
% of projects considering the factor	*36*	*71*	*50*	*71*	*79*	*64*	*29*	*29*	*57*	*14*	*43*	*50*	*29*	*14*	*29*	*79*	*50*	*29*	*21*

• Factor is considered in the project/paper; (empty box) Factor is not considered in the project/paper

Table 15 – Factors for intermodality in reviewed literature

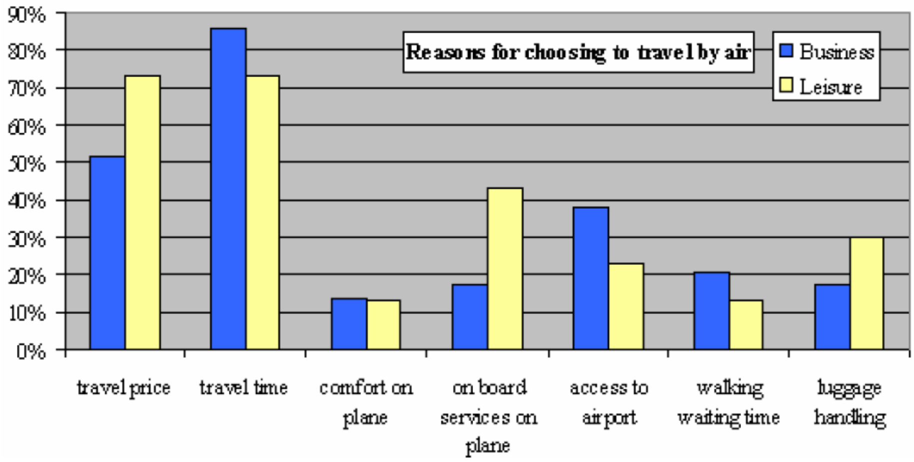
Travel time, notably including schedule coordination, and integrated ticketing are the factors most mentioned by relevant literature (79% of reviewed projects/papers). Ease of transfer factors related to physical issues, baggage handling and end to end check-in are also mentioned in most studies (71% of reviewed projects/papers). Service frequencies, schedule and capacity, and connection opportunities are also viewed as critical factors in over half the studies (64% of reviewed projects/papers). Logical ease of transfer is only a concern for half the reviewed authors, along with rail service and costumer care and product marketing. Only about one third of authors are concerned with access/egress issues, ticket price, delay assistance, passenger incentives, security and governance (29 to 43% of reviewed projects/papers). Most studies don't mention mode preference and legal and regulatory issues as success factors for air-rail intermodality.

It is important to mention that these studies look for factors of air-rail intermodality without offering recipes for intermodality success, rather their findings point to the inexistence of a "one best solution" – airports and operators may have to pursue different approaches for intermodal integration in order to best address their specific requirements.

4.4.2 Factor discussion

4.4.2.1 Travel time and ticket price

In her study about passenger air-rail intermodality, Cokasova (2006)'s approach treated air and rail modes as competitors and found that the most important travel attributes involved in mode choice for air (Figure 16, top) and rail passengers (Figure 16, bottom) were **travel price** and **travel time**.



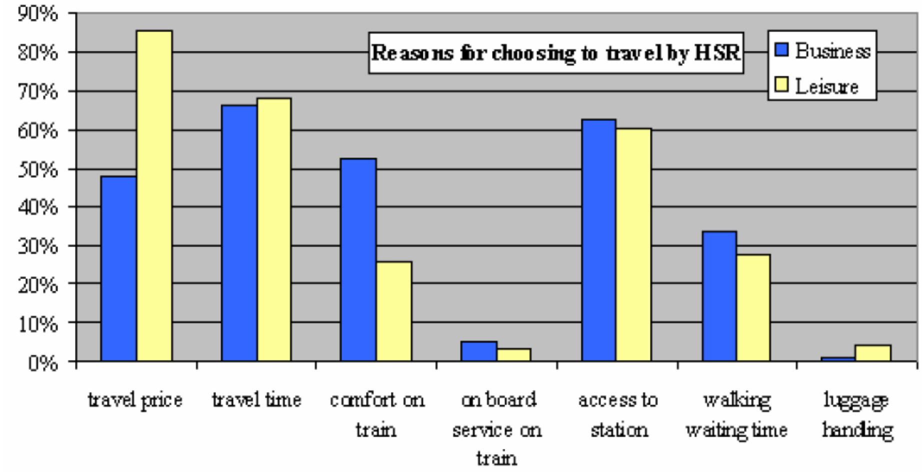


Figure 16 – Reasons for choosing to travel by air (above) or high-speed rail (below)
Source: Cokasova (2006), pp. 68-69

More recent findings by French DGAC (direction générale de l'aviation civile) also rank time and "cost" as critical factors for air rail intermodality. DGAC regularly conducts intermodal passenger surveys at Paris-CDG and Lyon Saint-Exupéry to assess air-rail intermodality performance in those two airports, which have integrated high-speed rail (TGV) stations (DGAC, 2009). Since 2005, the top reasons stated by intermodal passengers for using rail as a complementary mode to air have been the same, although their relative importance has changed: **lower cost**, **lower travel time** and the absence of an air link (Figure 17). The *absence of air link* factor in France can be associated with a policy of reducing or eliminating short-haul feeder air routes where high-speed train links exist directly to the airport.

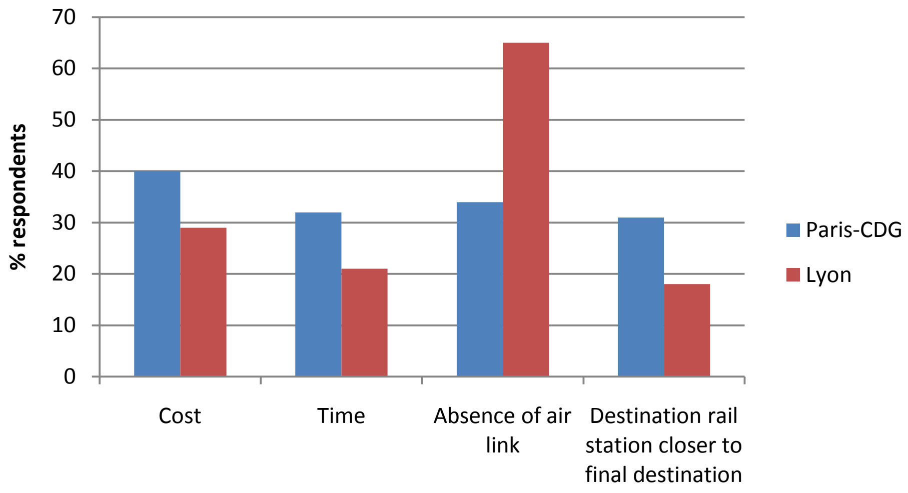


Figure 17 – Main reasons for using high-speed rail before/after flying
Source: Adapted from DGAC (2009), p. 19

A further note on time and price factors is that their importance varies with the demand segment we are considering. In fact, we can also say that most key elements in long-distance passenger intermodality **vary greatly across demand segments**. Based on expert panels, case studies and literature review, AEROAVE (2011) makes two distinctions– by motive for traveling and by range of journey – and summarizes the most import elements valued by each segment (Table 16). As expected, they found that time is an issue for business passengers, especially those on trips within Europe, as opposed to longer intercontinental trips; price is an issue for all leisure passengers.

	Motive	
Range	**Business**	**Leisure**
Intercontinental	Comfort Baggage handling Delay assistance Ease of transfer	Price
European long-distance	Travel time Security	Price Security

Table 16 –Elements most valued by passengers in air-rail intermodality
Source: Adapted from AEROAVE (2011), p. 18

Up to now in this subchapter, travel time is considered as *overall travel time*. Travel time in an intermodal journey is a sum of a lot of different parts, each depending on different actors and factors (Figure 18). Table 17 analyzes each component of overall travel time, associating them with their determining factors.

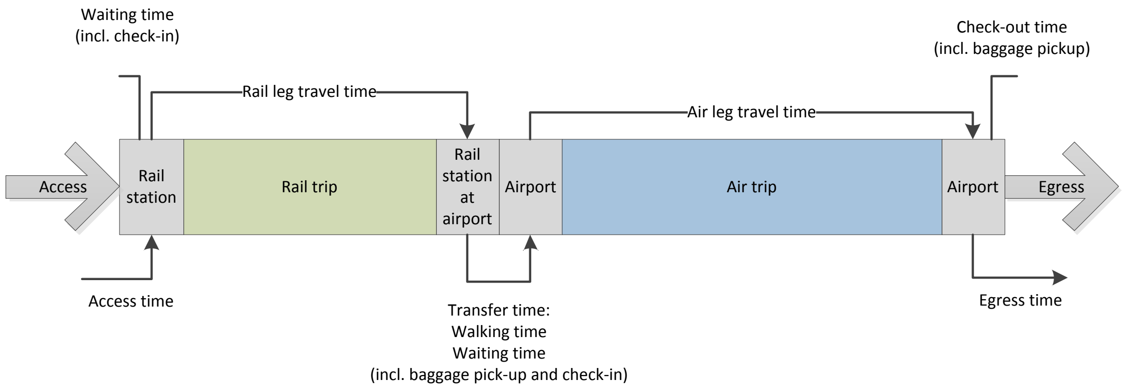


Figure 18 – Components of passenger overall travel time in air-rail intermodality

Component	Determining factors
Access time	**Rail station accessibility from main urban agglomerations** This factor is seen as an advantage of rail transport versus air transport – it is usually easier to reach a railway station as they are often in or nearer city centres. On the other hand, due to congestion and parking restrictions, rail station accessibility by private car can be worse, especially since they don't usually have parking facilities comparable to airports'.
Waiting time at the rail station	**Baggage handling** **Check-in at rail station** Waiting time at the rail station depends on how integrated the product is. More complex products offer baggage handling and check-in at the rail station, which means passengers get their boarding pass, go through customs, if needed, and check-in their baggage, which goes through security screening, at the rail station. In the case of integrated products, waiting time at the rail station should still be lower than for a flight, as entry railway stations generally need to manage fewer operations and users than airports. With integration, waiting time at the rail station is higher and waiting time during transfer

Component	Determining factors
	at the airport is reduced. It is to be expected that, with schedule coordination, waiting time at the airport is significantly reduced if check-in is transferred to entry rail station.
	Security Security screening requirements for baggage and passengers impact check-in time.
	Punctuality and reliability Less complex products have next to no waiting time, except when the question of train delays is accounted for.
Rail leg travel time	**Rail leg travel time** Rail leg travel time is considered a success factor on its own, as it is widely agreed that for this type of intermodal journey, a maximum of 3 hours is acceptable (Chi, 2004). So destinations considered for intermodal agreements need to be no further than 3 hours away, which makes high-speed rail a more attractive service for all involved, as it allows for a larger market. See also rail leg travel time compared to air leg travel time below, in the air leg travel time line.
	Punctuality and reliability Train delays impact rail leg travel time and can lead to loss of connection.
	Baggage handling One of the factors that could impact travel time is baggage handling – if a train journey has more than one entry rail station for integrated intermodal products, stops might need to be longer to allow for baggage loading (AEROAVE, 2011).
	Transfers in the rail leg It also accepted that the rail trip should be direct, without transfers (Eichinger, 2007), due to the issues of travel time and, mostly, passenger convenience.
Transfer time from the airport railway station to the terminal	**Ease of transfer (physical)** Infrastructure integration being a precondition of this study, physical ease of transfer factors related to transfer time translate into short walking time and length, with moving walkways when necessary. These are determined by interface design and management. Transfer time of a good practice airport should below 20 minutes, at railway station below 5 minutes.
	Ease of transfer (logical) Logical ease of transfer factors related to transfer time translate into clear signposting along the path and also real time information from the beginning of the journey until the end on terminals, gates, and timetables. Recently, personalized information services are recommended by some authors (AEROAVE, 2011).
	Baggage handling **Check-in at rail station** As was mentioned earlier, less complex intermodal products don't offer baggage handling or check-in at rail station, so these operations need to be done during transfer time. Passengers need to carry their baggage from the airport railway station into the check-in facility, obtain their boarding passes, clear through security screening and possibly customs. If these services are offered at the rail-way station, transfer time is potentially reduced by a large amount – aside from security screening, none of the previous operations need to be carried out during this time, although some time needs to be allowed for airport ground force baggage handling.
	Number of operating services To minimize the waiting times at capacity restraint points, a sufficient number of operating check-in desks/ticket counters/info-points/security checks/passport controls must be provided. At good practice interchanges the maximum waiting time should be below 5 minutes at peak hours. This means the requirement of adequate number of working staff during peak and off-peak times (KITE, 2009b).
	Security Security screening requirements for baggage and passengers impact check-in time.
	Schedule coordination This is a major factor of travel time, since it strongly determines the waiting time component of transfer time.

Component	Determining factors
	While usage level of waiting time at airports may be high, it adds to overall journey time, so connecting times cannot be too long for passengers. Schedule coordination between train arrival and flight departure must work at least as well as with air/air solutions at hub airports for intermodal travel to be able to compete. For this to happen, cooperation between airlines and rail operators is fundamental.
Air leg travel time	**Air leg travel time** Chi and Crozet (2004) found that it is for longer air trips (intercontinental long-haul flights) that passengers favor traveling a first leg by high-speed rail to the airport rather than by air. Rail leg time relative to air leg time in those cases is smaller and therefore more acceptable by the passenger. To illustrate this, recent data from French civil aviation shows that average flight time for intermodal passengers at Paris-CDG is about 8h, whereas at Lyon it is only about 3h. The former is considered best practice in France, with over 4% intermodal passengers and a volume of 60,5 million passengers a year. The latter is considered less a successful intermodality project, with only 0,5% intermodal passengers and a volume of 7,8 million passengers a year.
	Punctuality and reliability Airplane delays impact air leg travel time and can lead to loss of connection.
Check-out time	**Baggage handling** Check-out time depends on airport operations, baggage handling time being a major determinant.
	Ease of transfer (physical) Ease of transfer also applies to airplane to egress mode transfer. Again, interface design and management are critical factors as they determine walking time.
	Ease of transfer (logical) Again, the main factor is clear signposting along the path, only in this case towards specific egress mode terminals (buses, parking, taxis, for example).
Egress time	**Airport accessibility from main urban agglomerations** Airport access issues can translate into significant egress time. Road congestion is usually a problem around airports, but despite pressure to solve road access problems, with suburbs reaching into airport areas, noise and other environmental impacts have to be considered, as well as other space planning constraints. Road modes can therefore be strongly subject to delays. Funding for other modes is difficult to obtain, besides space planning constraints also apply.

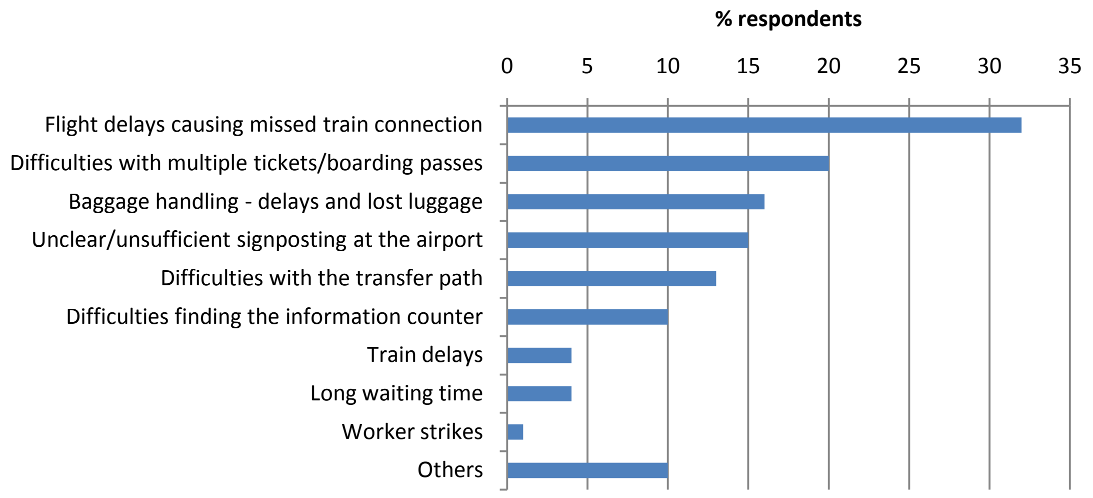
Table 17 – Factors affecting each component of overall travel time and related actors

Generalized travel cost is also considered a factor for intermodality (Janić, 2011). This factor takes into account both travel price and time by converting the latter into a cost through use of a value of time constant related to each demand segment.

An additional note on **schedule coordination** is due, since it is mostly mentioned independently of travel time, but has been grouped with it for analysis purposes. Compatibility of schedules is indeed a factor of major importance for the development of air-rail intermodality. Eurocontrol (2005b) mentions an example of how lack of schedule coordination limits the number of possible air destinations for an intermodal product: the earliest Thalys train from Brussels to CDG airport arrives at 09:04 at Paris-CDG and, considering that an airline such as Air France defines a “minimum connecting time” of 1 hour, all flights taking off before 10 AM are not available via the Thalys link; some long-haul destinations, especially towards North America, cannot consequently be part of an intermodal product.

4.4.2.2 Ease of transfer factors

DGAC (2009) asks passengers about what went wrong during their intermodal journey; replies are mostly about **transfer issues and associated time issues, such as delays and waiting time** (Figure 19).



Note: Baggage handling issues refer to the air leg, as no integrated baggage handling was available for surveyed passengers.

Figure 19 – Difficulties during the intermodal journey

Source: Adapted from DGAC (2009), p. 24

Transfer issues are also found to be critical factors by IATA (2003), who specifically asked passengers about sequential air-rail journeys and found that, aside from the inexistence of rail services at the airport, one of the main reasons stated by passengers for not using air-rail intermodal travel was **connection issues** (Figure 20).

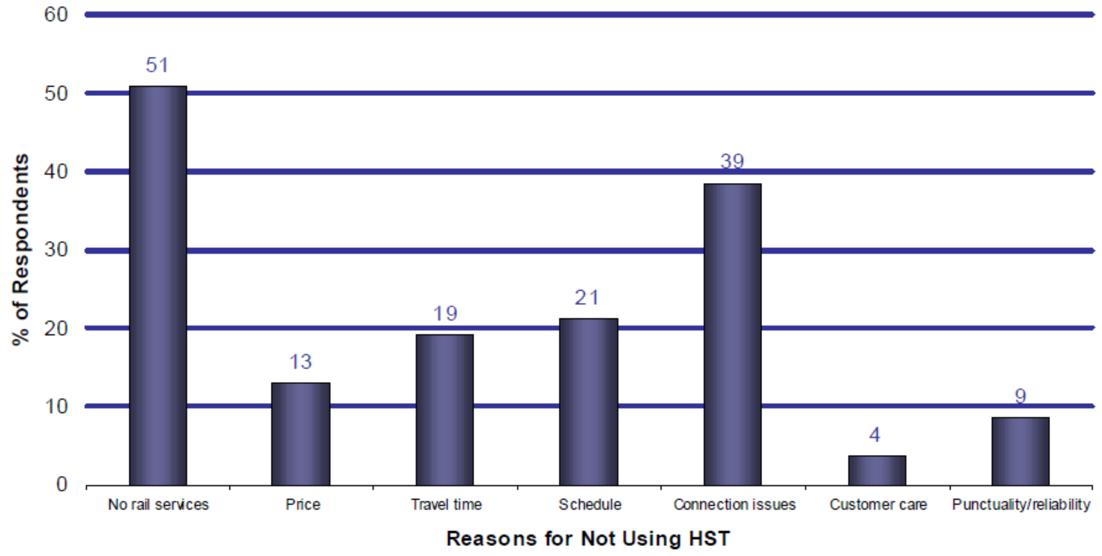


Figure 20 – Main reasons for not using high-speed rail before/after flying

Source: IATA (2003), p. 27

Connection issues need to be addressed in order to provide **seamless intermodal journeys**. Project KITE (2009b) presents extensive guidelines on providing seamless travel, including **design aspects of the intermodal interchange** and passenger services to support intermodality such as schedule coordination. From those guidelines we have selected the ones which are suited to air-rail intermodality (Table 18).

Ease of transfer factors	KITE guidelines
Short distances between rail station and terminal	The transfer between different long distance modes should be as comfortable as possible, therefore the distances between the terminal and the rail station should be short or shuttle services should be provided. Further a good understandable signage is required.
Walking time/distance	To minimize the transfer times between the long-distance modes, the walking distance between stops of the different transport modes must be minimized. Transport systems like elevators, conveyor belts or shuttle services can help minimizing the transfer time. Transfer time of a good practice airport should be below 20 minutes, at railway station below 5 minutes.
Amount/type of information	To support seamless passenger travel, sufficient information must be provided. This should include ideally real time information about: - arrival and departure times, - further connections, - other stops in the area, - delays or breakdowns - changes of platforms/gates/docks
Location of information	Information should be provided on visible locations considering passengers walking lines. This includes all terminal buildings as well as platforms/gates (also local public transport stops).
Different media	Previous key aspects require a sufficient number of good visible display panels, panels with diagrams/maps of services.
Further passenger services	The supply of help-points, inquiry counters or special personnel for questions able to speak different languages, call centres, internet hot spots is advantageous.
Information design	A consistent and understandable design of the information tools is recommendable. There is a lack of European and international standardization of the design for interface information.
Language of information	At interchanges with international passengers information should be provided in local language(s) and in English.
Amount of signage	To support seamless passenger travel the signage should include all public transport modes, taxi stops, car parks and cycle facilities, directional signs, especially for the location of platforms, gates or docks, ticket counters and security features, service facilities like information desks, toilets, waiting and shopping areas, pick-up points for luggage and telephones. Main principle is not to overload the signage and to make a clear distinction between official signs and advertisements.
Signage location	Signage should be located seamless in the building and over the whole area of the interchange under consideration of the passenger streams from, to and between all modes.
Signage design	If available, a standard design of colours, fonts, sizes and pictograms should be used.
"Language" of signs	English signage should be provided everywhere; a multilingual supply of information corresponds to a high quality service.
Type of check-in services	A good supply of different possibilities (e.g. self-check-in, pre-check-in) and locations (e.g. at railway stations in the city and in the catchment area of the interchange) to check-in at airports ensures a high comfort for the passengers and can further help to shorten waiting times for other passengers.

Ease of transfer factors	**KITE guidelines**
Short distances between transport modes and service facilities	The service facilities should be located in logical progression for the principal user group. Visual connections from different positions should be designed (surface/elevated situations). The use of glass for visibility and transparency supports the passengers' orientation to minimize walking distances at the interchange.
Intermodal luggage services	The offer of intermodal luggage services between long distance modes is crucial for seamless passenger travel and must be aimed for each intermodal interchange. Costs should be reasonable. This service requires a high cooperation between the operators.
Location of luggage pick-up and collection points	A good supply of different pick-up and collection points for the luggage increase comfort for the passengers
Further luggage services	Special services like door-to-door service for oversized luggage, pre- and self check-in for the luggage ease luggage handling for the passengers.
Barrier-free accessibility factors	Elevators and ramps: The interchange has to be equipped with elevators and ramps through the whole building. Those facilities have to be signed through the interchange. Guidance facilities: The interchanges should be equipped with voice messages, braille and tactile stripes on the floor for visually impaired people. For deaf people induction loops have to be installed. Barrier free rest rooms: The provision of barrier free rest rooms has to be ensured. Special Services: The provision of special skilled supporting staff during the operating hours is of evidence for a high quality of this service. Further advantageous is a supply of wheel chairs and of help phones. The support should be available also in the surrounding area of the terminal, not only inside. Information and promotion: All of the services for barrier free accessibility and interchange have to be promoted. Involvement: Especially during the planning, the involvement of special interest groups is very important.
Protection from weather	All of the passenger walking paths should be protected from weather.
Number of waiting areas/rooms	An adequate number of waiting areas/rooms supports convenient waiting conditions for long-distance travellers. Smaller closed areas are more comfortable for passengers because of less noise.
Location of waiting areas/rooms	The waiting areas should be spread over the whole terminal buildings, especially in the near of capacity restraint points.
Climatization of waiting areas	Weather protection and air conditioning for the waiting areas are desirable.
Equipment of waiting areas	Waiting conditions should be equipped with a sufficient number of seats, telephone/internet, information panels, special entertainment, toilets in low walking distance (30m), mother-child facilities (kid's corner, family areas) and marked-off smoking areas.
Waiting areas design	The terminal design, the cleanliness and the presence of security support a good feeling for the passengers and convenient waiting conditions.
Good feeling of safety and security	Presence of staff/police: Visible and uniformed staff and security services inside and outside the terminal buildings support a good feeling of security for the passengers. A balance should be found between uniformed and not uniformed patrolling staff and between private security staff and police. Competences of staff: The security staff should also be trained for personal care of the passengers. Security and police offices: Security and police stations should be offered at the interchange with opening hours adapted to the terminal operating hours. Technical visible features: Closed-circuit television (CCTV), help points and control barriers could increase the passengers' subjective good feeling of safety.

Ease of transfer factors	KITE guidelines
	The whole area of the interchange (including parking facilities) should be covered by CCTV. A balance should be found to ensure high security standards without disturbing the passengers.
Good supply of shops and facilities for daily use and consumption	Sales area: A reasonable supply of shops (sales area per passenger) and facilities for daily use and consumption leads to convenient waiting conditions for long-distance travelers. Branches: Different branches beyond supermarkets and gastronomy are desirable. Location: The shops and facilities should be located along the passenger streams within short walking distances. Opening hours: The opening hours of the shops and further facilities should be adapted to the opening hours of the interchange terminal. Special facilities/services: The offer of further special facilities like conference rooms, medical centres is advantageous; also special services like events, fairs, exhibitions or market days can support convenient waiting conditions.

Table 18 – Ease of transfer factors, according to KITE (2009b)

Source: Adapted from KITE (2009b), pp. 115-129

Eurocontrol (2005b) states that the most comprehensive, and the best strategy for encouraging people to use public transport for accessing to the airport is based on the concept that both the check-in process (issuing of the boarding pass) and the luggage acceptance process are undertaken off-airport at the railway station. While end to end check-in has become more common within intermodal products, baggage handling, despite being considered such a critical factor for intermodality, is not. In fact, it raises security issues and considerable operational difficulties and capital/operating costs; therefore it is not offered by reviewed intermodal products at this time (except at an additional cost).

EC (2006b) found that while no insurmountable technical difficulties with introducing through baggage handling seem to exist from a security perspective, the issue of cost is essential – capital and operating costs for through rail-air baggage handling are substantial and the evidence from the cases where it was introduced has been that the commercial benefits to participating airlines are unlikely to offset these costs.

When asked about baggage handling, air passengers and rail passengers did not value it highly for modal choice (Cokasova, 2006; Figure 16). Intermodal passengers at Paris-CDG do not complain of major difficulties carrying their luggage from the train station to the airport (Figure 21), but when asked if they were interested in through baggage handling, 84% of passengers stated they would be interested, mainly because transporting the luggage from the plane into the train station was tiring (60%) and because it would be more comfortable in general (52%). Reasons stated for not being interested in through baggage handling were concerns about lost or stolen luggage (61%), the option of accessing their luggage during the train leg (36%) and the fact that they mostly travel light (17%).

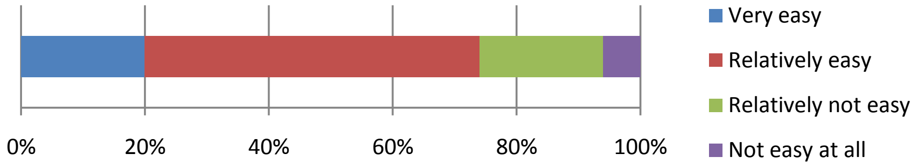


Figure 21 – Survey results on how easy it was for Paris-CDG intermodal passengers to transport their baggage from the train station to the airport
Source: Adapted from DGAC (2009), p. 27

4.4.2.3 Ease of access/egress factors

Access/egress conditions can be an important factor for air-rail intermodality success (Figure 22), as they very usually represent an advantage of the intermodal product. Cokasova (2006) found that 40% of passengers agree that access to the train station is a relevant reason for choosing to travel by rail, while only 9% of passengers share the same opinion about airport access.

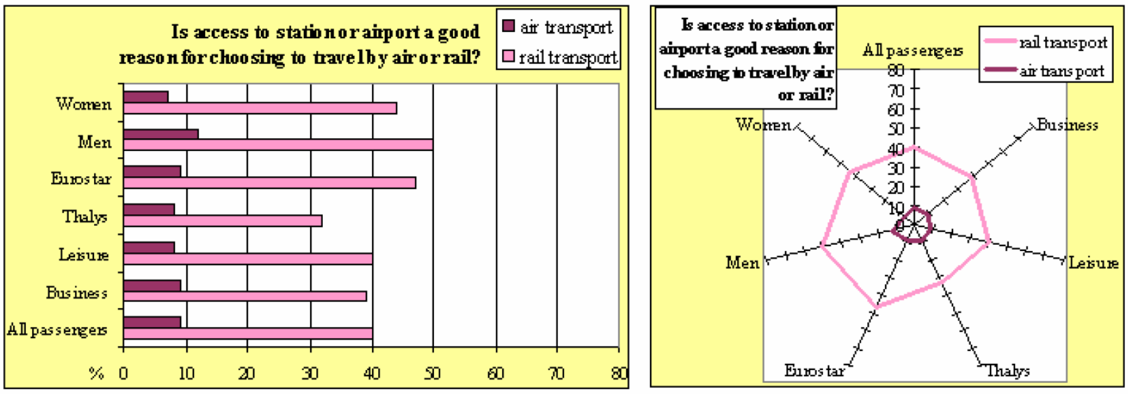


Figure 22 – Importance of access/egress conditions for air and rail passengers
Source: Cokasova (2006), pp. 58

Rail stations are usually closer to city-centres than airports and are well served by public transport whereas airports are usually situated in city outskirts which implies additional travel time for air passengers to reach the initial point of travel. Although the latter typically invest in good accessibility, overall travel times and convenience can be more favorable for the rail traveler (Figure 16, bottom; Figure 17).

Project KITE (2009b) includes as factors of this group the availability of foot paths and bicycle paths leading directly to the terminal for good integration in the surrounding network, and bicycle stands or deposit boxes, features which are more likely to be offered at a railway station than at an airport. However, rail stations at city-centres typically have some accessibility weaknesses for private car users – city-centre congestion and lack of parking at rail stations.

4.4.2.4 Marketing factors, mode preference and passenger incentives

Even an intermodal product which meets most passenger needs will not be competitive if it is not marketed properly. **Product visibility** or product awareness are considered critical success factors by many studies. Distribution over the internet is becoming increasingly important; also, common distribution, even if ticket integration doesn't exist, is crucial – while buying a ticket from any channel (airline website, travel agent, airline phone service, airport counter etc.), the customer is informed of rail feeders as well as air feeders, and has the option of purchasing either.

In their assessments of German intermodal products, Eichinger (2007) and Grimme (2007) value the possibility to earn frequent flyer miles from train feeders as a factor for intermodality. However, this is mentioned by a low percentage of air passengers when asked why they choose to travel by air (Cokasova, 2006). Frequent flyer points can nevertheless work as a good incentive for intermodal travel, as in the case of the TGVAir product, where passengers can earn more miles if they take the train rather than the plane.

DGAC (2009) asks passengers about what went wrong before (during preparation) their intermodal journey and replies reveal **communication and marketing weaknesses** (Figure 23).

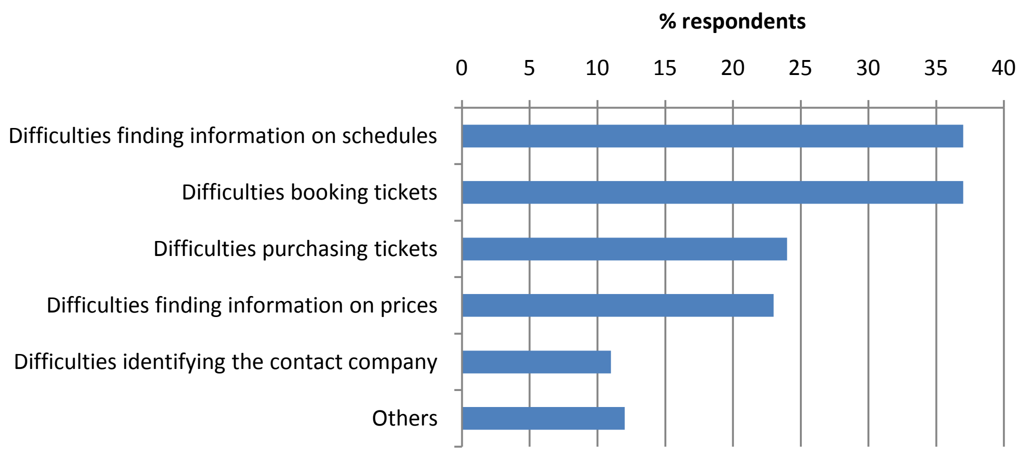


Figure 23 – Difficulties before the intermodal journey
Source: Adapted from DGAC (2009), p. 22

Further exploration of IATA (2003)'s results on the reasons not to travel by high speed rail before/after a flight unveiled that connection issues were put forward in higher proportion by passengers who had little or no experience of intermodal travel, which translates into an information and communication gap and some issues at interchange points for users. It also reveals that **passengers' perception regarding intermodal transport** can be a barrier to the success of air-rail intermodality, mostly due to expectations of poor connection conditions and due to the image of rail transport in some countries (Eurocontrol, 2005b).

For integrated intermodal products, information and promotion are therefore essential to force passenger demand (KITE, 2009b). Good marketing stands on an excellent supply of information, which must be obtained through cooperation between operators and permanent and/or periodical campaigns for customer feedback (Figure 24). **Continuous quality management** with appropriate tools is also a success factor. These include surveys/interviews targeting customers, employees, management and others, discussions/workshops, internal audits and external audits (Figure 25). The definition of concrete goals is recommended by KITE (2009b) – e.g. Vienna Airport set as goal keeping the waiting time for 95% of the passengers under 5 min.

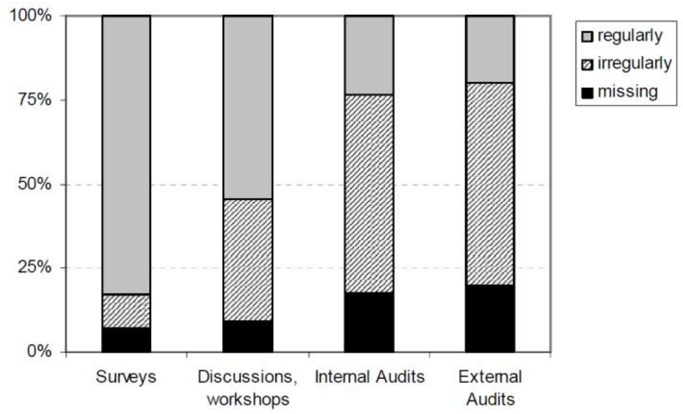


Figure 24 – Frequency of the application of different quality management tools for services at best practice interchanges
Source: KITE (2009b), p. 107

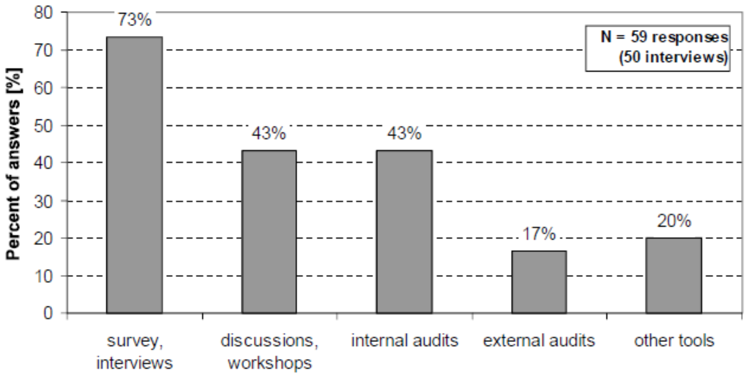


Figure 25 – Types of quality management system tools applied at good practice interchanges (multi responses possible)
Source: KITE (2009b), p. 105

Marketing research tools are key in determining the way the intermodal product is set up, whether by providing target locations, passenger segments, and quality of service requirements for a suitable intermodality system integration, or by determining specific attributes of the intermodal product such as the price that the customer is willing to pay, suitable promotions (such as points-per-miles) or even the place to advertise it. Marketing research tools, the data they retrieve and the conclusions they reach should be taken seriously as they provide the most reliable information on customer intentions and foresee the viability of an air-rail intermodal product.

4.4.2.5 Integrated ticketing

Operator side, the provision of integrated tickets can be made difficult by complex tariff structures and individual purchasing channels; passenger side issues are mostly the lack of promotion, the price and the availability of integrated tickets (HERMES, 2011b). In fact, while air-air tickets are sold together as one, air-rail tickets are not always easily purchased together. DGAC (2009) found that 88% of intermodal passengers coming through Paris-CGD travel with separated tickets for each leg. They state the reason for this is that passengers are unaware integrated tickets exist. 33% of passengers identify as an important improvement the generalization of the integrated ticket.

IATA (2003) found that the lack of an integrated product was stated as a reason not to use high-speed rail before traveling by air. From their case studies, they found that distribution of intermodal tickets was less convenient than air or rail only tickets. With the increase in ticketless travel, or e-ticket arrangements, intermodal product distribution is expected to have been improving. Also, e-ticketing has been associated with rapid bag-drop-off, which overall promotes cost-efficient check-in methods (EC, 2006b).

AEROAVE (2011) argues that integrated ticketing helps the passenger perceive the intermodal journey as a single journey and not the sum of different legs.

4.4.2.6 Frequency, schedule and capacity

According to Cokasova (2006), this factor ranks third in an importance scale for mode choice (between air or rail) for all passengers, after travel time and travel price. Air and rail frequencies determine transfer time, as well as schedule coordination, which impacts on overall travel time. Higher frequencies and different schedules also increase choice/travel opportunities for passengers. For Frankfurt, Vespermann and Wald (2011) relate the drop in feeder air passenger traffic with the success of rail alternatives in decreasing travel time and increasing frequency (Figure 26). Rail frequencies, according to the same study, are where Frankfurt intermodal product operators are investing next.

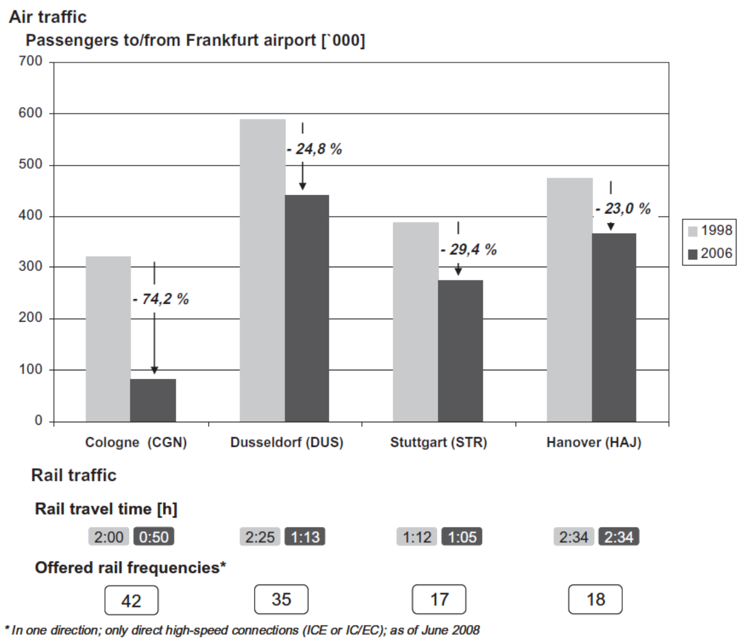


Figure 26 – Inner-German air and rail traffic between Frankfurt airport and selected cities
Source: Vespermann and Wald (2011), p. 1194

4.4.2.7 Reliability and punctuality and delay assistance

Reliability is a measure of how often a service is subject to severe disruption, for example due to strikes or engineering works. Punctuality is a measure of the proportion of services which run on time, when the service does run (EC, 2006b).

Among passenger concerns over using two different modes of transport on an intermodal journey of this type is a major apprehension over what happens in case of a missed connection if two operators are involved – who takes responsibility and who does the passenger address to solve their problem? The lack of assistance agreements in case of delays or cancellations was one of the intermodal product weaknesses found by IATA (2003) on their case studies, but most of the European intermodal products we reviewed for this study now offer delay assistance. Ticket flexibility is valued by some authors as an additional feature for intermodal products. For some users, namely business passengers, this feature adds value to the product, and consequently a few of the European intermodal products we reviewed offer it.

Reliability and punctuality as transport product attributes are extremely important when there is competition, which is mostly the case with intermodal products. Choosing to fly air-rail instead of air-air for these factors is not unusual when the interchange is a highly congested hub subject to regular delays. EC (2006b) compared a few journeys where rail market share has increased due to these factors:

- Eurostar market share on the London-Paris route increased substantially when they increased the proportion of trains arriving within 15 minutes of scheduled time from 79% to 89%; also, Eurostar managed to avoid many of the French rail strikes. Because

London-Heathrow and Paris-CDG are very congested, the air link between them is subject to more delays; the air service has also been affected by a number of strikes.

- On the Madrid-Seville route, RENFE achieves far better punctuality than any other operator on comparable routes, with over 99,5% of trains arriving within 5 minutes of scheduled time; rail market share for this route is over 85%.
- The relatively high market share on the Milan-Rome route may also be related to the poor punctuality achieved by Alitalia, the main airline for that route.

4.4.2.8 Connection opportunities and passenger volumes

These factors are associated with the network context. According to various authors, namely Chi and Crozet (2004), setting up air-rail links is more likely to be successful in a context:

- Where there are rail connection opportunities (sizeable urban agglomerations) within 3 hours travel time, and rail infrastructure is mostly in place, with available train slots;
- At airports which offer varied and frequent long-haul flights;
- At airports with high passenger volumes to justify rail integration investment.

AEROAVE (2011) elaborates on the need for high passenger volumes: airports must generate enough passenger demand to make it attractive for rail operators and rail infrastructure managers to invest on and operate a link; this factor explains the unsatisfactory intermodal performance of Lyon Saint-Exupéry airport (see subchapter 5.2).

4.4.2.9 Rail on-board comfort and customer service

Eurocontrol (2005b) state that passengers expect a similar level of service on all segments of the air-rail journey. Generally, air transport has higher quality standards higher than rail, but lately, this is not the case as frequently as before, with the growth of low-cost airlines. Business passengers are sensitive to services such as seat catering, work on-board possibilities (plugs for laptops) and talking on-board via cell phones. Some intermodal products offer “airplane” grade on-board service at trains – Thalys and ICE trains are examples.

4.4.2.10 Security

Security issues involve high-jacking of aircrafts, attacks on infrastructure (airports, railway tracks, railway stations) or trains. The 2001 attacks on the World Trade Center led to a tightening of security measures on all modes of transportation and this included ICAO refining security requirements. Tighter security takes up space for equipment, holding passengers, inspecting luggage. Normal security structure at airports allows for security inspections at the outset of movements and their termination. Transit passengers are usually funneled through the system in a secure pipe on the air side. Intermodal transportation poses additional costs within this structure (Button, 2003):

- The need to bond traffic through airports to avoid replication of security checks;
- The need to conform to the highest common denominator within modes and jurisdictions;
- The need to separate intermodal passengers from those who are only using high-speed rail.

In terms of security, the key priority in intermodal travel is to ensure that aviation security is maintained. There would be little benefit in increasing rail security for air-rail passengers if this was not applied to all rail passengers, as rail is generally an open system – transforming it into a closed secure system would imply significant costs and loss of convenience for all users. Intermodal passengers coming from the rail leg are therefore usually required to go through security at the airport and their luggage is also processed there (EC, 2006b). If operators wish to offer end to end check-in with through baggage handling, separation of rail traffic needs to be in place: separate secure train carriages for intermodal passengers, locked baggage containers, physical separation of paths from the train station to the terminal. For this to be possible, security checks need to be offered at the rail station, as well as baggage check-in and customs, which implies very high investment and operation costs for the operators involved in the intermodal product.

Security issues can determine whether an intermodal product can be sold to specific countries. As an example, Grimme (2007) states that it is a rather complicated and costly process for a foreign airline to make use of the AIRail service since they have to apply for approval at their home country's civil aviation authority, as AIRail is a deviation from standard security procedures found in international aviation; for failing to obtain this approval, airlines from the USA were not yet allowed to use the AIRail services on trips originating in Cologne or Stuttgart at the time of his study.

4.4.2.11 Governance factors

Governance factors include issues of cooperation and coordination among operators and public authorities, intermodal agreement, intermodal product business models and the existence of a coordinating authority for intermodal transfer nodes.

Cooperation between actors is a key factor for intermodal product success. Intermodal service agreements between operators are a binding legal basis for the exchange of information and the coordination of activities among operators (HERMES, 2011b).

There are many different kinds of intermodal service agreements between operators and these may involve other actors besides rail and air transport operators, namely airport managers, rail infrastructure managers, city managers, or police. According to KITE (2009b), intermodal contracts should include service quality level agreements with contents such as:

- Punctuality
- Reliability
- Minimal service stipulations
- Frequency
- Schedule coordination
- Equipment / on-board comfort
- Maintenance and cleanliness of terminals
- Luggage check-in and check-out facilities
- Integrated ticketing and revenue sharing
- Advertising, booking
- Information for passengers
- Quality management

Vespermann and Wald (2011) state that the existence of an intermodality coordinator at the airport is a key factor for the success of air-rail intermodality.

Other stakeholders are also involved in planning, implementing and operating intermodal interchanges. KITE (2009b) found that these external stakeholders are more involved in the planning stages and consist mainly of special interest groups (Figure 27).

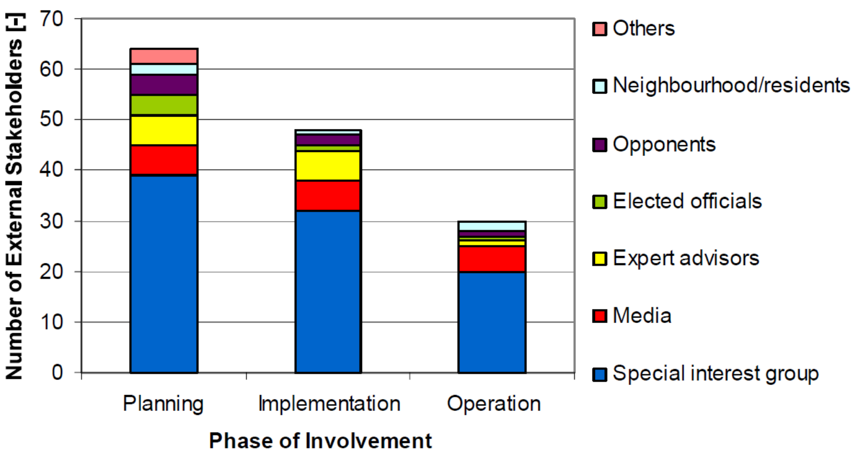


Figure 27 – Number of different groups of external stakeholders involved in the planning, implementation or operation phase of the service (multi responses possible)
Source: KITE (2009b), p. 102

Funding and the allocation of investment and operation costs is also an issue of governance which is critical for making air-rail intermodality happen. Major costs are associated with:

- Planning/building the airport railway station with adequate capacity
- Planning/building railway network (tracks) and making train slots available
- Planning/installing luggage check-in and check-out facilities at rail stations

- Installing security screening and customs offices facilities at rail stations
- Personnel for the operation of check-in, luggage handling, security, customs at rail stations
- Marketing and distribution of intermodal products

4.4.2.12 Legal and regulatory factors

Legal and regulatory factors determine air-rail intermodality projects mostly in the planning phase and include compulsory environmental impact assessment, local regulations on parking spaces, noise restrictions, safety regulations for tunnels at railway stations. KITE (2009b) argues that legal regulations are constraints of the intermodal project and need to be established intensively at the beginning by implementing a quality management system to permanently monitor all goals, time and cost and identify problems at an early stage.

4.4.3 Critical factors for air-rail intermodality success

While some authors thoroughly list factors for air-rail intermodality success, others, such as Chi and Crozet (2004) and AEROAVE (2011) look for the ones with a larger impact – the critical factors. Table 19 presents the five factors we have defined as critical from our review of literature and observation of current air-rail intermodal products and infrastructure in Europe. These are the factors we will further analyze on case studies.

The factors we considered in our literature review (subchapter 4.4.1) were regrouped in order to answer the question: "in which context is air-rail intermodality more likely to succeed?" and factor descriptions were added in the form of those answers.

Critical factor	Description "Air-rail intermodality is more likely to succeed…"
Infrastructure integration	At airports which have or plan to have railway stations
	At airports where spatial or project design constraints allow for good infrastructure integration, making the transfer between rail station and terminal as short, easy and comfortable as possible for the passenger
Network context	Where there are direct rail connection opportunities (sizeable urban agglomerations) within 3 hours travel time
	Preferably where rail infrastructure is mostly in place, with available train slots
	At airports which offer varied and frequent long-haul flights
	At airports with high passenger volumes to justify rail integration investment
Overall travel time and transfer time	On routes where it is possible to offer overall travel times which are competitive with air-air products
	Where operators agree to coordinate schedules to offer short waiting times at the intermodal transfer
Integrated ticketing	Where operators agree to offer integrated booking and purchase of intermodal tickets – one ticket for the entire intermodal journey
Information	Where operators agree to market their intermodal products adequately and to exchange information for their set up and operation

Table 19 – Critical factors of air-rail intermodality

From the beginning we found that factors were interrelated, which made it very complex to analyze them, be it individually or in groups. Having established the critical factors, we looked for their interrelations with the initial factors in our literature review. Table 20 presents this work, classifying interrelations as strong, regular, weak or non-existent. It is very interesting to find that all critical domains relate to governance and legal/regulatory factors. This shows us they are also critical as foundations of intermodal projects – legal/regulatory constraints strongly determine context and governance is key for planning, implementing and operating these multi-operator projects which require high levels of cooperation and coordination.

Groups of factors from literature review	**Critical factors**				
	Infrastructure integration	**Network context**	**Overall travel time, transfer time**	**Integrated ticketing**	**Information**
Ease of access/egress		•	••		
Ease of transfer at airport (physical)	•••		••		
Ease of transfer at airport (logical)	•••		••		
Ease of transfer at airport (baggage and check-in)	••		••	••	
Travel time	•	•	•••	•	
Frequency, schedule and capacity	•	•••	••		
Reliability and punctuality			••		
Delay assistance				•	•••
Connection opportunities and passenger volumes	•	•••	••		
Mode preference					•
Ticket price				•	•••
Rail on-board comfort and customer service					•
Passenger incentives					••
Flexibility				•	••
Security	••				
Integrated ticketing				•••	
Marketing				••	•••
Governance	••	••	••	•	•••
Legal and regulatory	••	•	•	•	•

••• Strongly related   •• Related   • Weakly related   (blank) Not related

Table 20 – Relating critical factors of air-rail intermodality with general factors found in our literature review

4.5 Relating critical factors with actors and success domains

All actors are related to critical factors of intermodality success in one way or another, through cooperation and coordination, as their input and activities are required for all phases of intermodality projects – planning, implementation and operation. In our present analysis, we looked into what were the strong relations between actors and critical factors of success (Table 21). As we had mentioned on chapter 3, we added city managers and high level policy makers to the initial list of actors. Also, relations with passengers were not included, as responsibility was the issue we were analyzing. For network context, strong responsibility can be attributed to most concerned actors: airlines for providing frequent long-haul flights, rail operators for providing direct frequent trains to sizeable agglomerations, airport managers for negotiating and garnering these links with airlines and train operators, rail infrastructure operators for providing train slots and implementing/maintaining train infrastructure all the way to sizeable urban agglomerations and higher level policy makers for promoting transport and regional planning policy towards a well functioning transport market and polycentric land use. Infrastructure integration is also a factor which presents responsibility across the actor list. Travel time, integrated ticketing and information are only strongly associated with transport sector actors – airlines, airport and rail infrastructure managers and rail operators are the stronger related actors.

Actors	Critical factors				
	Infrastructure integration	Network context	Overall travel time, transfer time	Integrated ticketing	Information
Airlines	•	•••	•••	•••	•••
Airport managers	•••	•••	••	•	••
Rail infrastructure operators	•••	•••	••	•	••
Rail operators	•	•••	•••	•••	•••
City managers	•••	•	•	•	•
Higher level policy makers	•••	•••	•	•	•

••• Strong relation   •• Average relation   • Weak relation

Table 21 – Relating critical factors of air-rail intermodality with actors

A simple relation between critical factors and success domains can be established (Figure 28) in order to verify that all success domains are included in the critical factors we are considering. Network context factors determine the number of intermodal destinations (they were therefore placed over the "large number of intermodal service destinations" axis on Figure 28). Infrastructure integration determines whether or not there is rail infrastructure connected to the airport (which is why this factor was placed over the "rail infrastructure connected to the airport" axis on Figure 28). All factors influence passenger demand, but overall travel time and information can be directly related to it as they strongly determine intermodal product attractiveness. Also, those two factors are highly related to the existence and contents of intermodal agreements – cooperation and coordination needed to market intermodal products, coordinate schedules in order to offer competitive travel times and transfer and provide information throughout the journey (which is why these two factors are placed diagonally on the "existence of intermodal agreements" and "high passenger demand" quadrant on Figure 28). Integrated ticketing depends on the existence of cooperation and coordination between actors as well (which is why this factor was placed on the "existence of intermodal agreements" axis on Figure 28).

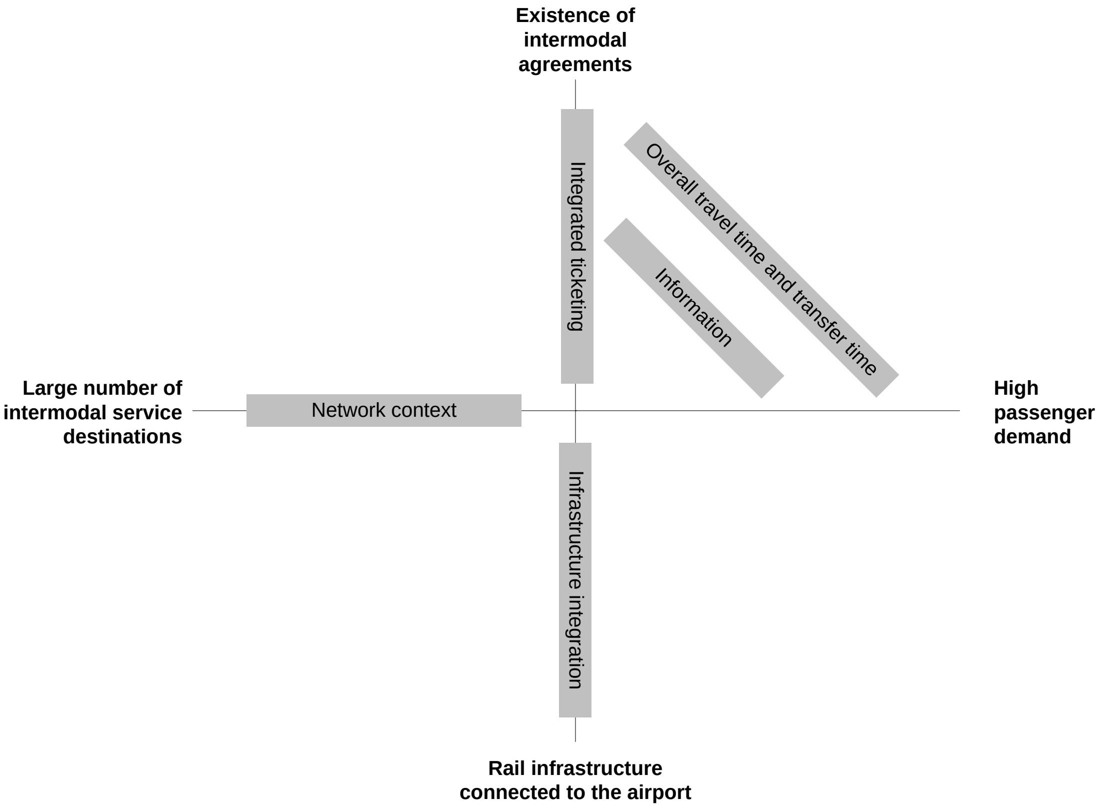


Figure 28 – Relating critical factors of air-rail intermodality with success domains

5 Case studies

Our first case study looks into best-practice in air-rail intermodality. Frankfurt airport and Paris-CDG are often rated as best-practice by literature (e.g. AEROAVE, 2010, Vespermann and Wald, 2011, Eurocontrol, 2005a) as well as by passengers (IATA, 2003). We chose Frankfurt airport and its Cologne link for our case study for data availability reasons and also because we used Paris-CDG for the second case study.

Our second case study looks into what makes airports succeed in air-rail intermodality by comparing a successful case with a not so successful case. For this case study, we chose Paris-CDG versus Lyon Saint Exupéry since data is available from DGAC and since they share regulation and operators, which narrows the domains of comparison.

Our third case study is an attempt to transfer results to Portugal. For this case study we chose Lisbon airport because high-speed rail infrastructure integration is more likely to be a possibility there than at Porto, Beja or Faro, at this time.

5.1 Case study 1: best practice

5.1.1 Frankfurt Airport

The long distance railway station at Frankfurt airport is a mainline station in the German high-speed rail network and the trans-European high-speed rail network.

Rail infrastructure integration started in the 1970 decade, with the opening of a regional train station at the airport. Since 1985, long-distance (intercity) trains also stopped at the airport regional station, but in 1999 a long-distance railway station was opened for the airport and these services were moved to it; from that station, it is possible to access intercity express services (ICE, Figure 29).

Figure 29 – ICE train departing from platform 4 at Frankfurt airport long-distance railway station (2009)
Source: Wikimedia commons, ICE 3 (Tz 354) im Fernbahnhof des Frankfurter Flughafens in Hessen (Deutschland) [http://en.wikipedia.org/wiki/File:Frankfurt_am_Main_Flughafen_Fernbahnhof-_auf_Bahnsteig_zu_Gleis_4-_ICE_403_554-9_(Tz_354)_18.10.2009.jpg]

In 2000, the AirRail terminal was opened to provide seamless air-rail intermodal journeys (among others, a baggage transport belt was installed; Figure 30).

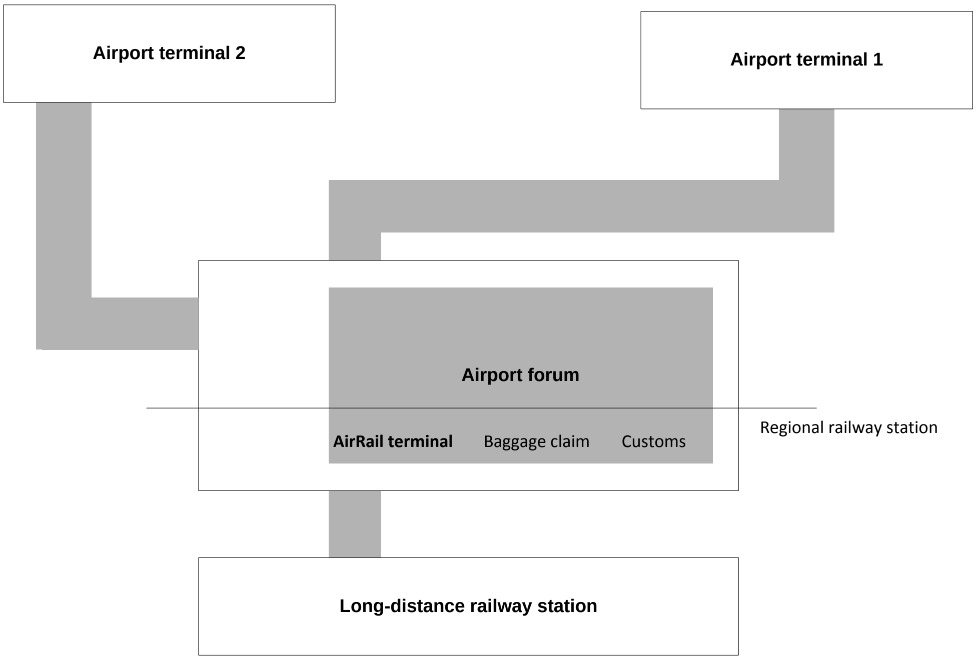


Figure 30 – Frankfurt airport schematics for air-rail journeys
Source: Adapted from Fraport in AEROAVE (2010), p. 122

In 2002, a railway corridor from the airport to the Rhine-Ruhr region was opened. That region is densely populated, which made the corridor project result in a significant increase in catchment. By opening up new catchment regions, more passengers can be attracted to the airport. In fact, Frankfurt airport has an extensive catchment of 38 million inhabitants living within a 200 km radius (which corresponds to less than 2 hours rail journey time) which can be associated with this region's polycentric land use pattern and wide-ranging transport network.

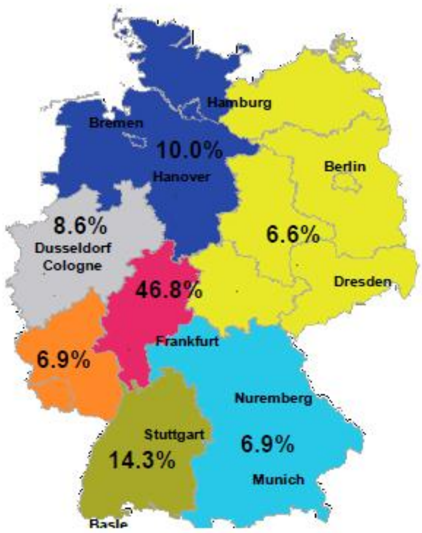


Figure 31 – Origin of Frankfurt airport's German passengers
Source: Fraport *in* AEROAVE (2010), p. 106

Additional demand in non-aviation activities (such as Frankfurt airport's popular conference centre) was generated at the airport by taking advantage of this increase in catchment and accessibility (Vespermann and Wald, 2011).

As of 2010, over 167 high-speed rail services are offered each day from Frankfurt airport station. 39 stations can be reached in less than 3 hours rail travel time (Figure 32).

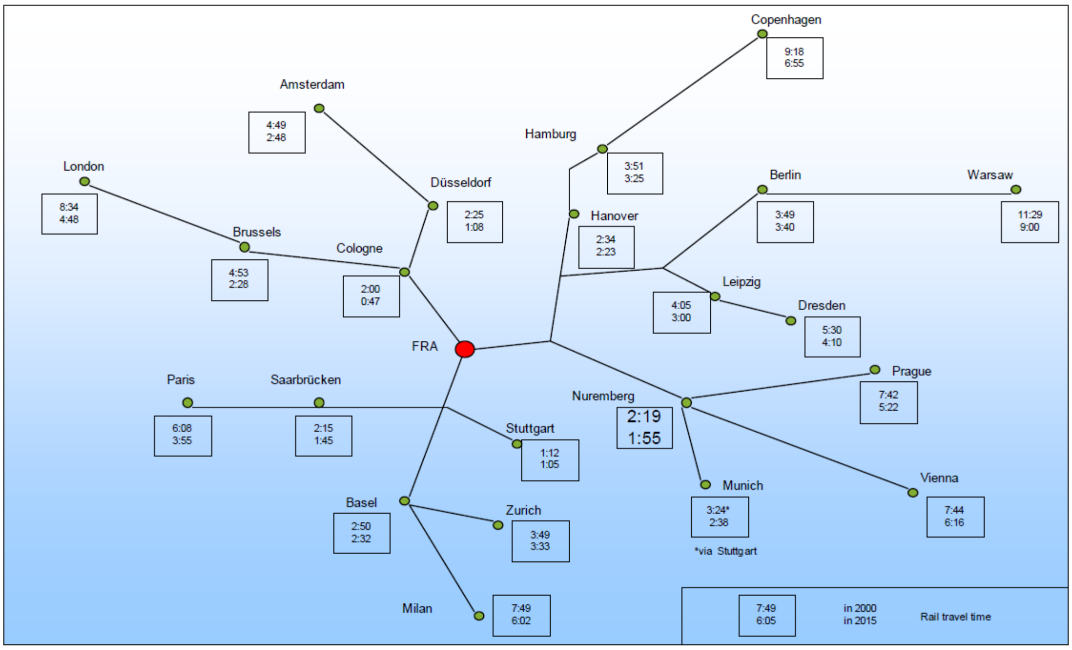


Figure 32 – Main rail destinations from Frankfurt airport: travel times for 2000 and 2015
Source: Fraport *in* AEROAVE (2010), p. 119

Frankfurt airport has an annual passenger throughput of 53,5 million (data for 2008) and it is the 3rd busiest airport in Europe in terms of passenger numbers and also air transport movements (486000 in 2008). Such high passenger traffic is related to the fact that Frankfurt airport is one of the main European intercontinental hubs – over 50% of passengers at Frankfurt airport are transfer passengers (AEROAVE, 2010).

5.1.2 Frankfurt-Cologne route – high-speed rail as feeder

The Frankfurt-Cologne route was one of the shortest distances flown in Germany – from one airport to the other, the great circle distance is 136 km (Grimme, 2007).

From 1989 to 2001, the number of yearly air passengers on this route was between 100000 and 170000. This included transfer passengers as well as origin-destination traffic, although the former were much more representative than the latter on global traffic (Figure 33).

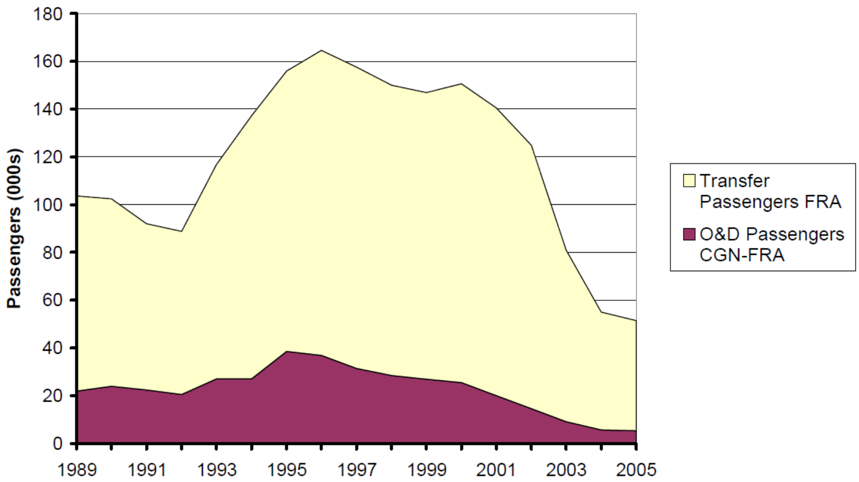


Figure 33 – Point-to-point and transfer passengers for the Cologne-Frankfurt air route
Source: EC (2006a), p. 100

Between 1995 and 2006, Lufthansa offered 4 to 7 daily air links for this route. In terms of rail offer, two main changes are visible in Figure 34: since 1999, many trains from Cologne to southern Germany and Switzerland were diverted to run via the new Frankfurt airport long distance railway station; the Cologne-Frankfurt high speed line opened in summer 2002, initially with an hourly shuttle service, and as a full service starting in winter 2002 (EC, 2006a). Rail travel time between Cologne and Frankfurt airport was reduced from 2 hours to 50 minutes with the introduction of high-speed services.

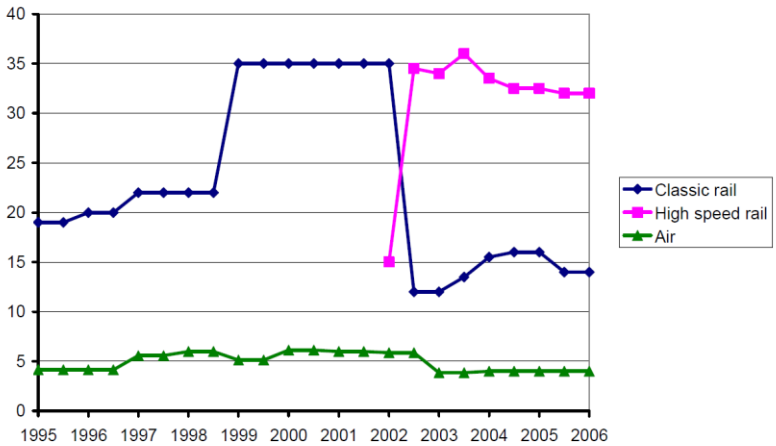


Figure 34 – Services per day and per direction for the Cologne-Frankfurt airport route
Source: EC (2006a), p. 98

The impact of the opening of the high-speed line between Cologne and Frankfurt airport in 2002 on air passenger demand can be seen on Figure 35. The introduction of the AirRail intermodal product further decreased the air link supply and demand in 2003. The number of available seats was reduced from more than 250000 to slightly more than 100000 annually, by means of a reduction in frequencies to a maximum of four per day and a reduction in average aircraft size to 73 seats (Grimme, 2007). The number of air passengers on this route was reduced by almost 75% from 1998 to 2006 (Figure 26, p. 52).

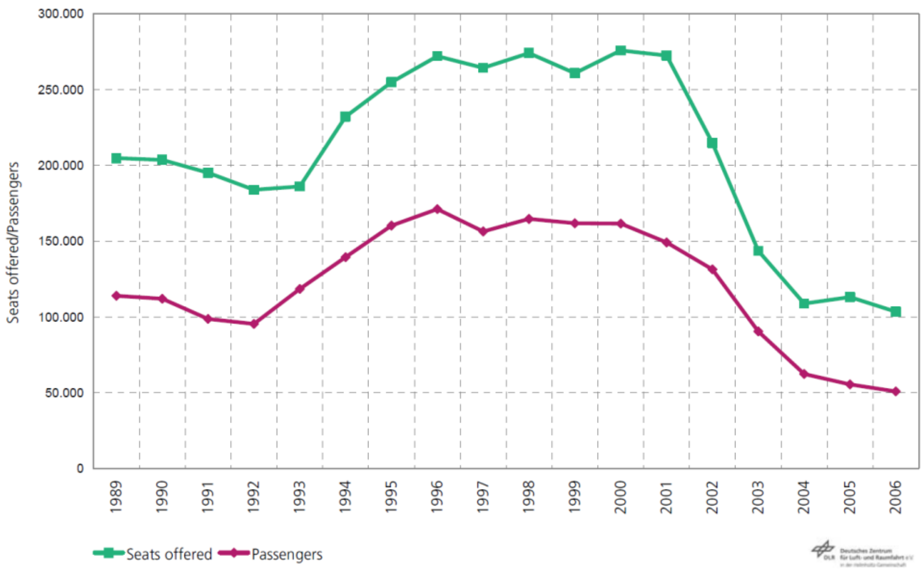


Figure 35 – Seats offered and passengers on air services between Cologne and Frankfurt
Source: Grimme (2007), p. 12

There were still a few origin/destination air passengers by 2006 – about 10% of total air passengers or about 5000 passengers annually. Although demand for air services was considerably reduced, train services did not fully replace air services until 2007, as Lufthansa argued they needed air feeders to retain especially premium passengers not willing to change to rail for issues of asymmetric information, relatively inconvenient access to train stations by private car and passenger perspective on rail services in general.

Discontinuation of air services between Cologne and Frankfurt was seen as a profitable action for Lufthansa for several reasons. Firstly, Lufthansa released up to four daily slots at Frankfurt airport, which is heavily constrained and operating at capacity limits during most of the day. Releasing these slots made it possible to expand Lufthansa's network from Frankfurt, with positive economic impacts for the airline, even taking into account the possible loss of premium air passengers who do not accept the train feeder. Secondly, crew and aircraft operating the low profitability Cologne-Frankfurt route could be used for more profitable routes. Thirdly, it was no longer strategically important to fly feeders from Cologne/Bonn airport since it was quickly being dominated by low-cost carriers flying point-to-point routes and network carriers had all withdrawn but one. The strategic risk of losing premium passengers not willing to accept rail feeders to other airlines was considered to be very limited. Currently, there are no flights from Cologne/Bonn airport to Frankfurt airport. The opportunity to gain miles for Lufthansa's frequent flyer programme from the AiRail leg of the journey was seen as a strategy to retain loyal Lufthansa passengers upon termination of air services (Grimme, 2007).

5.1.3 AiRail product for Frankfurt-Cologne

AiRail is the most advanced intermodal product in Germany and, probably, Europe. We refer to chapter 4.2 for general information on the AiRail product. On this case study, we looked only at specific attributes of the Cologne-Frankfurt service.

AiRail offers 16 daily links to Cologne – a high frequency which allows for considerably low waiting times for the intermodal passengers.

Strong points of the Frankfurt-Cologne AiRail product are the perception of seamlessness (except for baggage handling), the exemplary signposting at the transfer and the adequate on-board train service.

Since no air alternative exists at the moment, there is little competition for high-speed rail services from Cologne to Frankfurt airport for feeding long-haul air journeys. Nonetheless, despite low cost carrier domination at Cologne/Bonn airport, the issue of hub competition makes it important to maintain high standards for this service – if competitive air-air services are made available from Cologne/Bonn through another hub, Frankfurt risks losing long-haul market.

5.1.4 Intermodality manager and future investment

To support intermodal integration, the airport manager created the position of "intermodal manager" within the airport planning department (Vespermann and Wald, 2011). This manager is a coordinator of all operators, managers and authorities operating at the airport. His main concern is to promote the success of intermodality through cooperation and coordination of actors and activities.

According to Vespermann and Wald (2011), further improvements on intermodal integration at the airport are likely to focus at an extension of check-in facilities and of baggage handling systems at the AIRail terminal, a better matching of air-rail schedules and an increase in train frequencies.

5.1.5 Summary and conclusions

Frankfurt airport is considered best practice in air-rail intermodality for several reasons. Intermodality has brought benefits to all actors involved in making it happen, but with considerable investment and ambitious goals.

Table 22 shows indicators for air-rail intermodality success calculated for Frankfurt airport in 2004 by Eurocontrol (2005a). Table 23 analyses the presence of our critical factors in this case study. Additional features we found relevant on this case study were:

- The existence of an intermodal manager to coordinate actors and activities
- The interrelationship between rail services and non-aviation activities – the rail link benefits non-aviation activities by improving catchment and accessibility, whereas

additional rail demand generated from non-aviation activities makes rail links more profitable

Category		Indicator	Values for Frankfurt airport (2004)
Supply	Infrastructure	Number of rail infrastructures connected to the airport	2 (a regional station and a long-distance station)
	Operators	Yearly ASKs of airlines having intermodal agreements, over the total number of ASKs at the airport	88%
	Service	Number of intermodal destinations by air relative to the total number of destinations	76%
		Number of intermodal destinations by rail	6000
Demand	Demand	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	13%

Table 22 – Macro level indicators for Frankfurt airport integration

Source: Adapted from Eurocontrol (2005a), p. VIII

Critical factor	Frankfurt airport Cologne-Frankfurt route
Infrastructure integration	There is a long-distance train station with a dedicated AiRail terminal at the airport. Although the transfer was not inspected for this study, literature claims it is easy and comfortable, although not as short as transferring between Lufthansa flights (however, that should depend on the terminals involved).
Network context	There are many direct rail connection opportunities within 3 hours travel time – the catchment is over 38 million inhabitants. Rail infrastructure in place allows for 39 stations to be reached by high speed rail services within 3 hours journey time. It has been developing – it was only in 2002 that the Cologne high-speed corridor started operation. 167 high-speed rail services are offered each day from Frankfurt airport to those 39 stations. Frankfurt airport offers varied and frequent long-haul services as an intercontinental hub for Lufthansa and Star Alliance. Yearly passenger throughput is about 53,5 million.
Overall travel time and transfer time	The Cologne-Frankfurt route is offered by AiRail in 50 minutes. Transfer times are made short by good infrastructure integration and high rail frequencies (16 daily trains from Cologne to Frankfurt).
Ticket integration	AiRail offers integrated booking and ticketing through code-sharing; it is distributed online at numerous websites, notably from Lufthansa.
Information	AiRail is a joint venture of Lufthansa, DB and Fraport. Marketing tools have been used to start the product, define its features, monitor performance and adapt it. Cooperation and coordination of activities, as well as all the information exchange needed between actors is facilitated by an intermodal manager at the airport.

Table 23 – Critical factors at Frankfurt airport, considering the Cologne-Frankfurt route

5.2 Case study 2: comparing a successful case with one which is not so successful

5.2.1 Differences in passenger demand

In 1994, the French airports of Paris-CDG and Lyon Satolas were integrated in the high-speed rail network with the opening of their railway stations. This was seen as a major step in the interconnection of air and rail networks, which had become a goal of French transport policy, but results were strikingly different – Paris-CDG grew to become a success in air-rail intermodality whereas, in spite of the development of air traffic, of a dynamic region, of the existence of high-speed rail links and of airport and operator efforts, Lyon did not achieve such success (Chi and Crozet, 2004).

Table 24 shows these striking differences between Paris-CDG and Lyon for 2008.

	Paris-CDG	Lyon Saint-Exupéry
Rail passengers stopping at the airport railway station	3,4 million	416000 [(1)]
Intermodal air-rail passengers	2,5 million	40000 [(1)]
Share of intermodal air-rail passengers at the airport railway station	73%	8,10%
Total air passengers	60,5 million	7,8 million
Intermodal air-rail passengers / total air passengers	4,1%	0,5%

[(1)] Values estimated by DGAC

Table 24 – Summary of passenger demand for Paris-CDG and Lyon Saint-Exupéry airports
Source: Adapted from DGAC (2009), p. 5

Development of air rail intermodality at these airports has also been very different. From DGAC's data we can see that there is a regular increase in Paris-CDG yearly intermodal air-rail passengers and share of intermodal air-rail passengers (Figure 36). This growth at Lyon happened only in the most recent survey interval (from 2008 to 2011), while the numbers had been practically unaltered since 2002 (Figure 37).

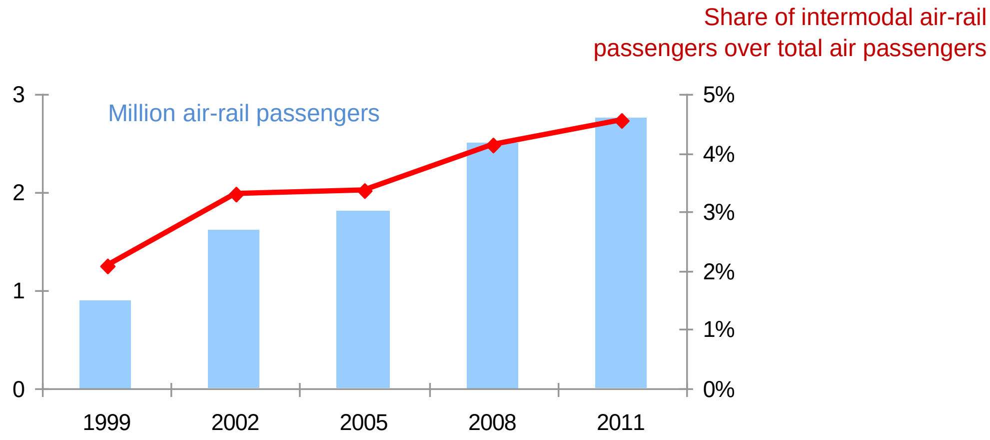


Figure 36 – Intermodal air-rail passengers and respective share over total air passengers for Paris-CDG
Source: Adapted from DGAC (2011), p. 3

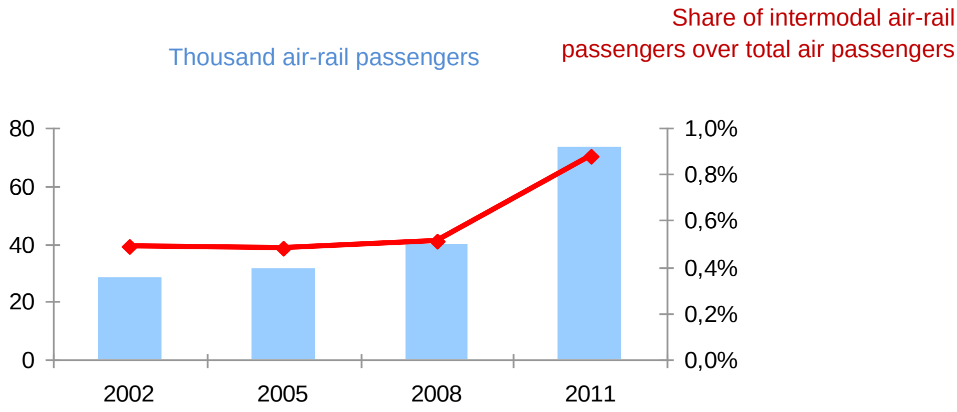


Figure 37 – Intermodal air-rail passengers and respective share over total air passengers for Lyon Saint Exupéry
Source: Adapted from DGAC (2011), p. 3

5.2.2 Key differences in transport supply

Based on available data and literature, it is possible to identify 4 key differences in transport supply which can account for the differences in passenger demand between Paris-CDG and Lyon.

The first one is airport size in passenger volume (total air passengers in Table 24). It is interesting to point out that French railway stations at airports aren't part of the rail networks which serve the cities, rather they are part of a high-speed rail network which avoids city centres (Chi and Crozet, 2004). Therefore, they need to become destinations on their own to justify the operation of trains which avoid urban agglomerations. Airport size in passenger volume here works a measure of how much an airport can stand on its own as a destination and make rail operation viable. Looking at the values on Table 24, Paris-CDG is about 8 times the size of Lyon airport in air passenger numbers. In 2010, it was 2nd in the European ranking of airports by passenger volume, whereas Lyon was 49th.

For smaller size airports such as Lyon, installing and maintaining a high-speed rail link needs to be justified by more than the expected intermodal air-rail traffic – additional (local) rail demand must exist to top up intermodal traffic, which is made difficult by the eccentricity of the rail station and network (Chi and Crozet, 2004), as well as rail/rail transfer traffic.

The second key difference is rail frequency, which comes as a consequence of the first. During the period of analysis, very low frequencies were offered for high-speed rail links from Lyon – the only relevant frequencies were towards Paris; from Valence, Grenoble or Chambéry there were 2 to 3 trains each day to and for Lyon airport (data from Chi and Crozet, 2004), and since schedule coordination wasn't a concern, intermodal transfer times became very high; moreover, with frequent air transport delays, the possibility of a missed connection with a very low frequency train becomes a major hindrance for the passenger.

The third key difference is the provision of intercontinental long-haul flights at the airport. While Paris-CDG is one of three major intercontinental hubs for Europe, Lyon is a regional platform with a directional vocation to Northern Africa countries.

Evidence for this issue is the long-haul intercontinental air link to New York which was opened in 2000 at Lyon by Delta airlines – by 2001 it was closed for lack of profitability, especially related to low business class demand (this air link was opened and closed again two more times; its last flight was in 2009).

DGAC (2009) found that intermodal passengers at Paris-CDG are mainly connecting to long-haul flights (over 60%) whereas at Lyon most connections are for European/Mediterranean destinations and a significant 25% of intermodal passengers connect to domestic flights (Figure 38).

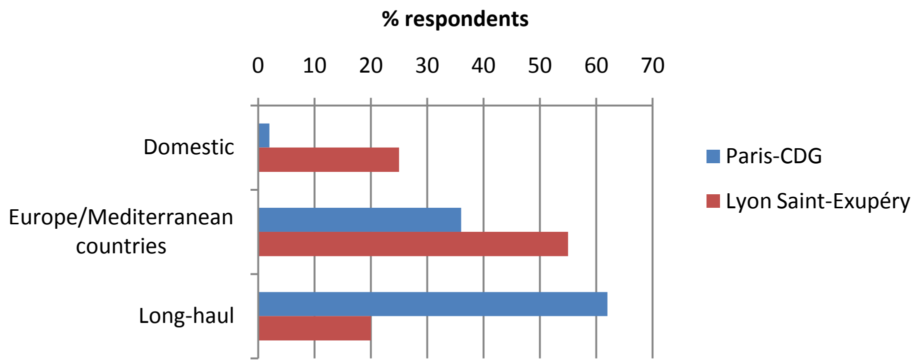


Figure 38 – Flight destinations for rail-air passengers from Paris-CDG and Lyon Saint-Exupéry
Source: Adapted from DGAC (2009), p. 13

Consequently, average travel times are also very different – average air leg time for intermodal journeys for Paris-CDG is as high as 7h36 for 2011, whereas for Lyon it is only 3h35; both have average transfer times between 3h and 3h30; average rail leg time for Paris-CDG intermodal journeys is also higher, at a proportion similar to the one found for average air leg time (Table 25).

	Paris-CDG	Lyon Saint-Exupéry
Average air leg time, including transfers	7h36	3h35
Average rail leg time	2h09	1h14
Average rail to air transfer time	3h23	3h01

Table 25 – Average travel time for air rail intermodal passengers in Paris-CDG and Lyon Saint-Exupéry
Source: Adapted from DGAC (2011), pp. 6-7

The fourth key difference is the existence of intermodal products from Paris-CDG which are tailored to attract air-air passengers towards the rail-air alternative they promote and which, in one case, have now replaced the air-air option (the Air France Brussels link by Thalys). These products offer integrated ticketing, schedule coordination, and end to end check-in for many destinations, resulting from cooperation between operators towards selling intermodality. At Lyon, the lack of an intermodal product is a barrier to the development of air-rail intermodality.

5.2.3 Summary and conclusions

The key differences found between the successful and the less successful cases are all relatable to our critical factors: the first three refer to network context (airport size in passenger volume, rail frequencies and provision of long-haul flights) and the fourth (provision of intermodal products) refers to integrated ticketing and information. Table 26 summarizes the key differences between these two airports within our critical factors.

Critical factor	Paris-CDG	Lyon Saint-Exupéry
Infrastructure integration	There is a TGV station at the airport.	There is a TGV station at the airport.
Network context	There are many direct rail connection opportunities within 3 hours travel from Paris-CDG, as well as varied and frequent long-haul services, as this airport is an intercontinental hub for several airlines. Yearly passenger throughput is about 50,5 million.	There several direct rail connection opportunities within 3 hours travel from Lyon airport, but very few long-haul services. Yearly passenger throughput is about 8 million.
Overall travel time and transfer time	Transfer times are made short by good infrastructure integration, high rail frequencies and schedule coordination. Intermodal passengers' average transfer time is 3h23.	Intermodal passengers' average transfer time is 3h01 – this value is for the intermodal links which are in demand by passengers. For other potential intermodal combinations, transfer times are unattractive due to low rail frequencies and no schedule coordination.
Ticket integration	The air-rail intermodal product TGVAir offers integrated ticketing and online booking and purchasing. The same is true for Air France's Brussels link by Thalys.	Ticket integration is not offered for air-rail journeys coming through Lyon airport.
Information	Cooperation and coordination of activities, as well as all the information	No air-rail intermodal products were found for this airport and no evidence of

Critical factor	Paris-CDG	Lyon Saint-Exupéry
	exchange needed between actors are part of the operator agreements for TGVAir and the Brussels link by Thalys.	operator coordination and information exchange was found.

Table 26 – Critical factors at Paris-CDG and Lyon Saint-Exupéry airports

5.3 Case study 3: Transferability of results to Portugal

Our attempt to transfer results to Portugal focuses on Lisbon airport because high-speed rail infrastructure integration is more likely to be a possibility than for Porto, Beja or Faro, at this time. The Portuguese high-speed rail network could potentially include a stop at a possible future airport which is to serve the urban agglomeration of Lisbon (Figure 39). That possibility is the basis for this study, where we try to find if there are conditions for air-rail intermodality success with Lisbon as an intermodal interchange and which main factors need to be taken into account when assessing such a possibility. We based our study on the high-speed rail network which was discussed and assessed in 2004 for Portugal.

5.3.1 Critical factors of air-rail intermodality at Lisbon airport

Infrastructure integration factors would have to be dealt with intensively at planning stage, the main issue being that the railway station is indeed at the airport and that the transfer between modes is as short, easy and comfortable as possible.

Network context factors would have to be dealt with intensively at viability assessment stage, but also throughout planning, implementation and operation, since improving network context is extremely important, be it by negotiating with airlines or lobbying for public investment in more rail infrastructure.

From the planned network, there are several direct rail destinations within 3 hours rail travel time which can be considered from Lisbon (RAVE, 2004):

- On the Lisbon-Porto axis, Oeste, Leiria, Coimbra, Aveiro, Porto
- On the Porto-Vigo axis, Braga, Valencia, Vigo
- On the Lisbon-Madrid axis, Évora, Badajoz-Elvas, Cáceres, Mérida, Plasencia, Talavera de la Reina, Madrid

Catchment for the airport would increase substantially, considering that Lisbon and Porto are the major Portuguese urban agglomerations, that there are several stops at medium-sized cities and that Madrid is a very largely populated urban area within 3 hours travel time (although this is on a no stops rail trip, which might not be a high frequency rail product to start with).

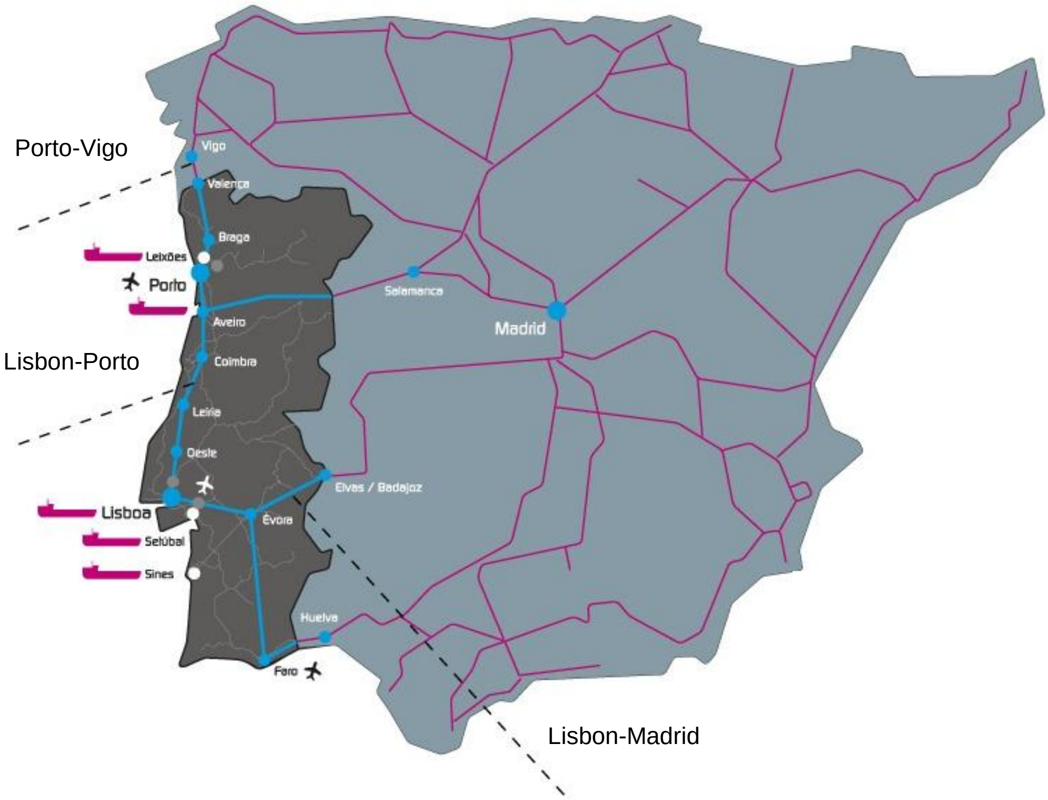


Figure 39 – High-speed rail network planned for Portugal in 2004

Source: Refer website

[http://www.refer.pt/LinkClick.aspx?link=conteudos%2fimagens%2fTransporteFerroviario%2fMapa-Peninsula_20120405_L.jpg&tabid=687&mid=801]

The provision of good rail frequencies for these destinations is key for the success of intermodal products as they determine connection opportunities and transfer/waiting time. In this study, we have found that this is best achieved when intermodal agreements exist which define minimum frequencies for rail. Also, best practice shows non-aviation activities help increase rail demand and contribute to maintaining high frequencies.

The provision of long-haul flights at the Lisbon airport will strongly determine passenger demand for air-rail intermodal products. For 2010, regular intercontinental flights were available from Lisbon to the following destinations (ANA, 2011):

- In Africa: Argel, Bissau, Boa Vista, Cairo, Casablanca, Dakar, Johannesburg, Luanda, Maputo, Marrakech, Praia, Sal, Sao Tomé, Sao Vicente, Tunis
- In North America: Boston, Philadelphia, Montreal, Newark, Toronto
- In Central and South America: Belo Horizonte, Brasilia, Caracas, Fortaleza, Natal, Recife, Rio de Janeiro, Salvador, São Paulo

Intercontinental passenger traffic at Lisbon airport has actually grown strongly in the last years. Frequencies for flights to Brazil have been increasing and diversification of destinations in Africa has also been impacting intercontinental demand (Figure 40). Emerging economies such as those in South America and Africa have a high potential for air traffic growth, therefore increasing frequencies reinforces a strategic position towards Lisbon airport being a directional hub for Brazil and certain African destinations from Europe and vice-versa.

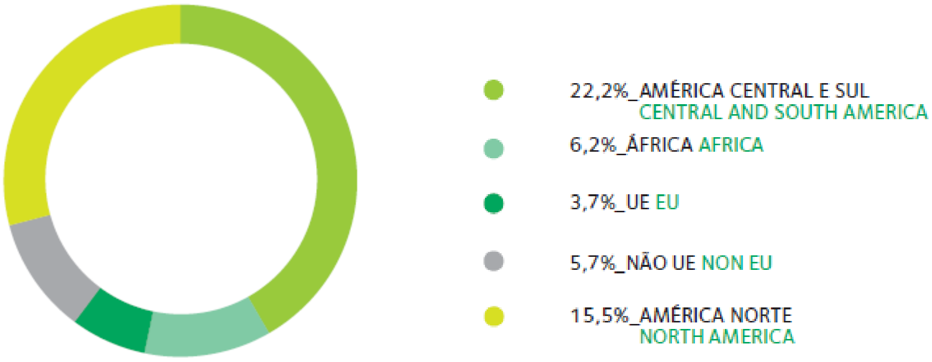


Figure 40 – Passenger traffic by world region at Lisbon airport

Source: ANA (2011), p. 20

Airport size in passenger volume has also grown in the past decade at an average annual rate of 4,1% (Figure 41). Lisbon airport was, as of 2010, the 29th European airport in passenger volume.

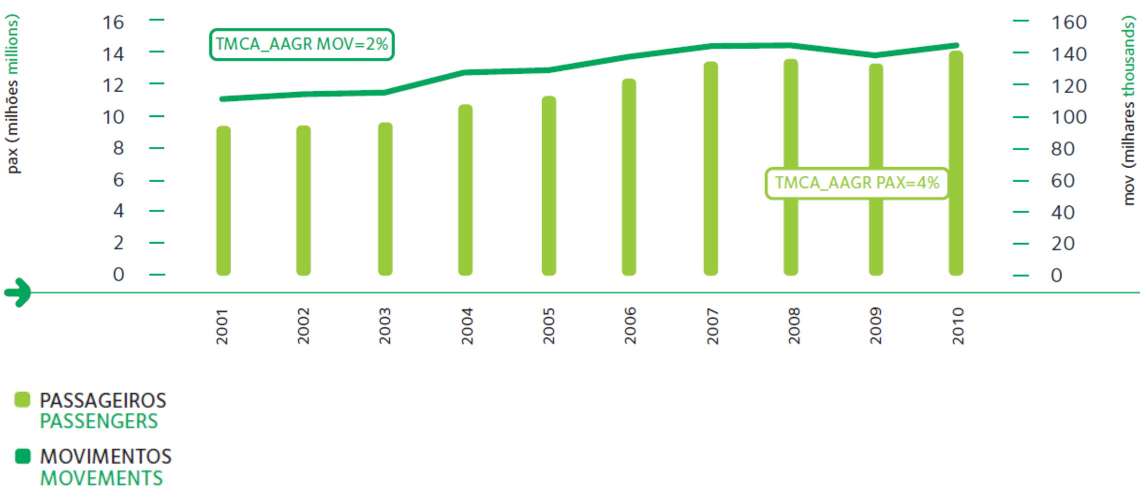


Figure 41 – Passengers and movements at Lisbon airport

Source: ANA (2011), p. 6

Overall travel times and transfer times would have to be dealt with intensively during product planning stage, preferably by cooperating operators, by choosing potentially successful adequate combinations of air and rail legs and by negotiating agreements for short transfer time with features such as minimum train frequencies or schedule coordination. Theoretically, there is a potential for attractive overall travel times for the all the air-rail journeys with rail legs below 3 hours, which corresponds roughly to the links to the urban agglomerations we listed for the catchment area.

Transfer times would also have to be dealt with intensively during the project planning stage, as interchange design will establish the level of integration, which in turn determines how short and easy the transfer is.

Ticket integration and **information** are two other issues to be dealt with intensively during product planning stage by cooperating operators.

5.3.2 Summary and conclusions

Lisbon airport is not a major European hub, although there is a potential for growth as a directional hub towards South America and possibly some destinations in Africa. Passenger values are average and potential catchment within 3 hours direct rail journey time will be larger with the implementation of the high-speed rail network. Assessment of an air-rail intermodality project in Lisbon should provide answers to the following questions:

- Will there be enough demand to justify high rail frequencies, including intermodal and local demand? High rail frequencies, together with schedule coordination, should guarantee short transfer times, preferably under 3h30, which is the highest value we found in our case studies.
- Will the expected provision of long-haul flights from Lisbon airport be sufficiently attractive to capture demand from other hubs? Or will the opposite happen?
- Is there operator interest in setting up intermodal products at Lisbon airports?

6 Conclusions

Air-rail intermodality projects involve considerable capital and operating costs and require ambitious goals and strong cooperation among actors.

We have defined five critical factors which determine air-rail intermodality success:

- Infrastructure integration: air-rail intermodality is more likely to succeed at airports which have or plan to have railway stations and where spatial or project design constraints allow for good infrastructure integration, making the transfer between rail station and terminal as short, easy and comfortable as possible for the passenger
- Network context: air-rail intermodality is more likely to succeed where there are direct rail connection opportunities (sizeable urban agglomerations) within 3 hours travel time, preferably where rail infrastructure is mostly in place, with available train slots, at airports which offer varied and frequent long-haul flights and which have high passenger volumes to justify rail integration investment
- Overall travel time and transfer time: air-rail intermodality is more likely to succeed on routes where it is possible to offer overall travel times which are competitive with air-air

products, where operators agree to coordinate schedules to offer short waiting times at the intermodal transfer

- Integrated ticketing: air-rail intermodality is more likely to succeed where operators agree to offer integrated booking and purchase of intermodal tickets – one ticket for the entire intermodal journey
- Information: air-rail intermodality is more likely to succeed where operators agree to market their intermodal products adequately and to exchange information for their set up and operation

Additionally, legal and regulatory constraints strongly determine context and should be dealt with intensively during planning stages.

Governance factors were also considered a key determinant of success for planning, implementing and operating these multi-operator projects which require high levels of cooperation and coordination. In this context, best practice shows that the existence of an intermodal coordinator or manager to coordinate actors and activities will facilitate air-rail intermodal operation.

Case study results illustrate the importance of the critical factors we considered earlier, as well as the role of cooperation and governance in air-rail intermodality success. Case study 3 suggests that it is possible to gather conditions for the successful integration of Lisbon airport in the high-speed rail network, and proposes the consideration of 3 main issues when assessing such a possibility:

- Will there be enough demand to justify high rail frequencies, including intermodal and local demand?
- Will the expected provision of long-haul flights from Lisbon airport be sufficiently attractive to capture demand from other hubs? Or will the opposite happen?
- Is there operator interest in setting up intermodal products at Lisbon airports?

Although best practice definitions and guidelines exist for intermodality in general, there doesn’t seem to be a recipe or one best solution for air-rail intermodality success. Further research is needed on how factors impact passenger demand in order to develop better decision support tools for air-rail intermodality projects.

7 Bibliography

AEROAVE (2010): *Primer Informe de Seguimiento*. Proyecto AERO-AVE. FEDEA,INNAXIS, ETT, FFE. [http://www.aeroave.es/ficheros/documentos/publicos/D1documentos_Informe_Seguimiento_1.pdf]

AEROAVE (2011): *La intermodalidad AEROAVE: Recomendaciones y propuestas para España.* Proyecto AERO-AVE. FEDEA,INNAXIS, ETT, FFE. [http://www.aeroave.es/ficheros/documentos/publicos/D4RecomyConcl_AEROAVE.pdf]

ANA (2011): *Relatório anual de tráfego '10 - Lisboa*. ANA aeroportos. [http://webresources.ana.pt/Relatorios/Relatorios_de_Trafego/LISBOA/index1.html]

ATAG, ACI & IARO (1998): *Air rail links: guide to best practice*. Air Transport Action Group, Airport Council International, International Air Rail Organisation.

BOOTSMA, P. D. (1997): *Airline flight schedule development: analysis and design tools for European hinterland hubs*. Elinkwijk B.V, Utrecht.

BURGHOUWT, G. (2007): *Airline network development in Europe and its implications for airport planning*, Aldershot, Hampshire, England; Burlington, VT, Ashgate.

BURGHOUWT, G. & DE WIT, J. (2005). *Temporal configurations of European airline networks*. Journal of Air Transport Management, 11, 185-198.

BUTTON, K. (2002): *Debunking some common myths about airport hubs*. Journal of Air Transport Management, 8, 177-188.

BUTTON, K. (2003): *The European Market for Airline Transportation and Multimodalism*. Report of the One Hundred and Twenty Sixth Round Table on Transport Economics held in Paris on the 20th-21st March 2003 on the topic *airports as multimodal interchange nodes*, pp 5-40. Paris, European Conference of Ministers of Transport.

CHI, A. (2004): *Do High-speed Trains Really Promote Interconnected Airports?* Presentation to the European Transport Conference, 2004, Strasbourg. [http://www.etcproceedings.org/paper/do-high-speed-trains-really-promote-interconnected-airports]

CHI, A. & CROZET, Y. (2004): *L'intermodalité TGV/AIR: quel second soufle pour la gare de Lyon Saint Exupéry TGV?* Transports, 428, 360-366.

COKASOVA, A. (2006): *Analysis of Passenger Viewpoints and of the Practical Shift in Air Rail Intermodal Transport*. Thesis for the degree of Philosophy Doctor in Transport and Communication Technologies, University of Zilina. [http://www.dit.hcmut.edu.vn/~vuduong/Family_files/Thesis%20COKASOVA%20A..pdf]

DGAC (2009): *Enquête sur la complémentarité modale TGV/Avion – Synthèse des résultats 2008*. Presentation of the Direction Générale de l'Aviation Civile, France. [http://www.developpement-durable.gouv.fr/IMG/pdf/Presentation_synthese_internet-2.pdf]

DGAC (2011): *L'enquête 2011 sur la complémentarité TGV-avion en France*. Presentation to the colloquium *TGV-AVION: une alliance d'avenir?* on 25-11-2011. Direction Générale de l'Aviation Civile, France. [http://www.developpement-durable.gouv.fr/IMG/ppt/TGV_Avion_Bouffard_Savary_vexport.ppt]

DUFF, A. (2002): *Airports as multimodal interchange nodes - the example of London Heathrow*. Report of the One Hundred and Twenty Sixth Round Table on Transport Economics held in Paris on the 20th-21st March 2003 on the topic *airports as multimodal interchange nodes*, pp 119-150. Paris, European Conference of Ministers of Transport.

EC (1995): *European Commission Green Paper The citizen's network: Fulfilling the potential of public passenger transport in Europe*. Brussels: European Commission COM(95)601. [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:1995:0601:FIN:EN:PDF]

EC (1997): *Intermodality and intermodal freight transport in the European Union*. Brussels: European Commission COM (97) 243. [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:1997:0243:FIN:EN:PDF]

EC (1998): *COST 318: interactions between high-speed rail and air passenger transport. Final report*. Luxembourg Lanham, Md., Office for Official Publications of the European Communities; Bernan Associates distributor.

EC (2000): *GUIDE: Group for Urban Interchanges Development & Evaluation. Final Report.* Prepared by MVA Limited for the European Commission DG VII. [http://www.transport-research.info/Upload/Documents/200310/guide.pdf]

EC (2001): *European Commission White Paper: European transport policy for 2010: time to decide*. Brussels: European Commission COM(2001) 370. [http://europa.eu/scadplus/leg/en/lvb/l24007.htm]

EC (2004): *Towards passenger intermodality in the EU. Report 1: Analysis of the key issues for passenger intermodality.* Produced by ILS-NRW, Babtie Spol., Langzaam Verkeer, ETT for the European Commission, DGTREN. [http://www.ils-forschung.de/down/towards-pass-1.pdf]

EC (2006a): *Air and Rail Competition and Complementarity, case study report.* Produced by Steer Davis Gleave London for the European Commission, DGTREN. [http://ec.europa.eu/transport/rail/studies/doc/2006_08_case_study_air_rail_competition_en.pdf]

EC (2006b): *Air and Rail Competition and Complementarity, final report*. Produced by Steer Davis Gleave London for the European Commission, DGTREN. [http://ec.europa.eu/transport/rail/studies/doc/2006_08_study_air_rail_competition_en.pdf]

EC (2006c): *Keep Europe moving – Sustainable mobility for our continent. Mid-term review of the European Commission's 2001 Transport White Paper*. Communication from the Commission to the Council and the European Parliament COM(2006) 314 [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0314:FIN:EN:PDF]

EC (2009): *A sustainable future for transport: Towards an integrated, technology-led and user friendly system*. Brussels: European Commission COM(2009) 279. [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0279:FIN:EN:PDF]

EC (2011): *European Commission White Paper: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*. Brussels: European Commission COM(2011) 144. [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0144:FIN:EN:PDF]

EICHINGER, A. (2007): *Characteristics and competitive implications of air rail links in Germany*. World Review of Intermodal Transportation Research, 1, 264-285.

EICHINGER, A. & KNORR, A. (2004): *Potential and Limitations of Air-rail Links – A General Overview*. Materialien des Wissenschaftsschwerpunktes "Globalisierung der Weltwirtschaft", 34. Institut für Weltwirtschaft und Internationales Management, Bremen University. [http://www.iwim.uni-bremen.de/publikationen/pdf/w034.pdf]

EUROCONTROL (2004a): *Review of the current intermodality situation*. CARE II: The airport of the future: Central link of intermodal transport? European Organisation for the Safety of Air Navigation. [http://www.eurocontrol.int/care-innov/gallery/content/public/docs/innov2/m3/WP1%204.0.pdf]

EUROCONTROL (2004b): *Scenarios of future evolution of the European transport network*. CARE II: The airport of the future: Central link of intermodal transport? European Organisation for the Safety of Air Navigation. [http://www.eurocontrol.int/care-innov/gallery/content/public/docs/innov2/m3/WP1%204.0.pdf]

EUROCONTROL (2005a): *Airport intermodality indicators*. CARE II: MODAIR: Measure and development of interMODality at AIRport. European Organisation for the Safety of Air Navigation. [http://www.eurocontrol.int/care-innov/gallery/content/public/docs/projects2005-2006/modair/WP1%201.1.pdf]

EUROCONTROL (2005b): *Potential airport intermodality development*. CARE II: MODAIR: Measure and development of interMODality at AIRport. European Organisation for the Safety of Air Navigation. [http://www.eurocontrol.int/care-innov/gallery/content/public/docs/projects2005-2006/modair/WP2_1.1.doc]

GIVONI, M. & BANISTER, D. (2006): *Airline and railway integration*. Transport Policy, 13, 386-397.

GIVONI, M. & BANISTER, D. (2007): *Role of the Railways in the Future of Air Transport*. Transportation Planning and Technology, 30, 95-112.

GRIMME, W. 2007. *Experiences with advanced air-rail passenger intermodality – the case of Germany*. Presentation to the Air Transport Research Society World Conference 2007. Berkeley. [http://www.dlr.de/fw/Portaldata/42/Resources/dokumente/paper/GRIMME-NR206.pdf]

HERMES (2010): *HERMES: High efficient and reliable arrangements for crossmodal transport. Deliverable 1: State of the Art on Crossmodal Transport Arrangements*. Work Package Team: CERTH. [http://www.hermes-7fp.eu/images/HERMES_D1.zip]

HERMES (2011a): *HERMES: High efficient and reliable arrangements for crossmodal transport. Deliverable 3: Regulatory and legal requirements: Identification of barriers and enhancement measures for interconnectivity.* Work Package Team: UPM-TRANSyT in collaboration with KIT-IWW. [http://www.hermes-7fp.eu/images/HERMES_D3.pdf]

HERMES (2011b): *HERMES: High efficient and reliable arrangements for crossmodal transport. Deliverable 4: Interoperability barriers to intermodality and interconnectivity of passenger transport.* Work Package Team: KIT-IWW in collaboration with UPM-TRANSyT (Fluhrer, T., Szimba, E., Siegele, J.) [http://www.hermes-7fp.eu/images/HERMES_D4.pdf]

IATA (2003): *Air/rail intermodality study*. Prepared by IATA Air Transport Consultancy Services for the European Commission, Airports Council International, Air Transport Action Group, the Community of European Railway and Infrastructure Companies (CER) and the International Union of Railways. [http://ec.europa.eu/transport/rail/studies/doc/2003_air_rail.pdf]

JANIĆ, M. (2007). *The sustainability of air transportation: a quantitative analysis and assessment.* Aldershot, Hants, England ; Burlington, VT, Ashgate.

JANIĆ, M. (2011): *Assessing some social and environmental effects of transforming an airport into a real multimodal transport node.* Transportation Research Part D, 16, 137-149.

JANIĆ, M. & REGGIANI, A. (2001). *Integrated transport systems in the European Union: an overview of some recent developments*. Transport Reviews, 21, 469-497.

KITE (2007): *KITE: a knowledge base for intermodal passenger travel in Europe. Deliverable D1: Central Issues in Passenger Intermodality.* Work Package Team: Institute for Transport Studies, University of Karlsruhe and STRATA GmbH. [http://kite-project.eu/kite/cms/images/stories/kite/WP1/D1%20-%20Central%20Issues%20in%20Passenger%20Intermodality.pdf]

KITE (2009a). *KITE: a knowledge base for intermodal passenger travel in Europe. Deliverable D11: Guidelines for assessing intermodal measures under data availability constraints.* Work Package Team: TIS.pt. [http://kite-project.eu/kite/cms/images/stories/kite/WP4/D11%20-%20Guideline%20for%20Assessing%20Intermodal%20Measures%20under%20data%20availablility%20constraints.pdf]

KITE (2009b): *KITE: a knowledge base for intermodal passenger travel in Europe. Deliverable D14: Guideline for seamless intermodal interchanges.* Work Package Team: Institute for transport studies (University of Natural Resources and Life Sciences, Vienna). [http://kite-project.eu/kite/cms/images/stories/kite/WP5/D14%20-%20Guidelines%20for%20Seamless%20Intermodal%20Interchanges.pdf]

KOUWENHOVEN, M. (2008). *The Role of Accessibility in Passengers' Choice of Airports*. OECD/ITF Joint Transport Research Centre Discussion Paper No. 2008/14 OECD Publishing. [http://www.internationaltransportforum.org/jtrc/discussionpapers/DP200814.pdf]

LINK (2009): *LINK: the european forum on intermodal passenger travel. LINK Working Groups Recommendations.*

LÓPEZ PITA, A. (2003): *Alta velocidad y conexiones aeroportuarias. Barcelona*, Edicions de la Universitat Politècnica de Catalunya; Centro de Innovación del Transporte.

RAVE (2004): *Estudo de mercado e avaliação socioeconómica e financeira da linha de alta velocidade Madrid-Lisboa/Porto*. Produced by EPYPSA for AVEP and Rede Ferroviária de Alta Velocidade (Portugal). [http://www.refer.pt/MenuPrincipal/TransporteFerroviario/AltaVelocidade/Estudos/Listagemdeestudos/tabid/686/id/170/Default.aspx]

RILEY, P. & KUMPOŠTOVÁ, A. (2010): *Recommendations of the LINK project: European forum on intermodal passenger travel*. Presentation to the European Transport Conference 2010. Glasgow, Scotland, UK. [http://www.etcproceedings.org/paper/recommendations-of-the-link-project-european-forum-on-intermodal-passenger-tra]

STUBBS, J. & JEGEDE, F. (1998).: *The integration of rail and air transport in Britain*. Journal of Transport Geography, 6, 53-67.

TAPIADOR, F. J., BURCKHART, K. & MARTÍ-HENNEBERG, J. (2009). *Characterizing European high speed train stations using intermodal time and entropy metrics*. Transportation Research Part A: Policy and Practice, 43, 197-208.

VESPERMANN, J. & WALD, A. (2011): *Intermodal integration in air transportation: status quo, motives and future developments*. Journal of Transport Geography, 1187-1197.

WIDMER, J.-P. & HIDBER, C. (2000): *Effects of rail stations at airports in Europe*. Presentation to the 79th Annual Meeting of the Transportation Research Board. Washington, D.C., 8-13 January 2000. [http://e-collection.library.ethz.ch/eserv/eth:25450/eth-25450-01.pdf]

WIDMER, J.-P. & HIDBER, C. (2001): *Do rail stations at airports allow a better distribution of passenger demand among airports?* Presentaton to the 80th Annual Meeting of the Transportation Research Board. Washington, D.C., 7-11 January 2001. [http://e-collection.library.ethz.ch/eserv/eth:24344/eth-24344-01.pdf]

Airport websites:

Amsterdam-Schiphol Airport (AMS): www.schiphol.nl

Birmingham Airport (BHX): www.birminghamairport.co.uk

Brussels Airport (BRU): www.brusselsairport.be

Budapest Airport (BUD): www.bud.hu

Cologne/Bonn Airport (CGN): www.koeln-bonn-airport.de

Copenhagen Kastrup Airport (CPH): www.cph.dk/

Düsseldorf Airport (DUS): www.dus-int.de

Frankfurt Airport (FRA): www.frankfurt-airport.com

Friedrichshafen Airport (FDH): www.fly-away.de

Geneva Airport (GVA): www.gva.ch

Glasgow-Prestwick Airport (PIK): www.glasgowprestwick.com

Leipzig/Halle Airport (LEJ): www.leipzig-halle-airport.de

Lisbon Portela Airport (LIS): www.ana.pt/

London-Gatwick Airport (LGW): www.gatwickairport.com

London-Luton Airport (LTN): www.london-luton.co.uk/

London-Stansted Airport (STN): www.stanstedairport.com

London-Southend Airport (SEN): www.southendairport.com

Lübeck Blankensee Airport (LBC): www.flughafen-luebeck.de

Lyon-Saint Exupéry Airport (LYS): www.lyonaeroports.com

Manchester Airport (MAN): www.manchesterairport.co.uk

Milan-Malpensa Airport (MXP): www.milanomalpensa1.eu

Oslo-Gardermoen Airport (OSL): www.osl.no

Paris-CDG Airport (CDG): www.aeroportsdeparis.fr

Pisa Galileo Galilei Airport (PSA): www.pisa-airport.com

Rome Leonardo da Vinci-Fiumicino Airport (FCO): www.adr.it/fiumicino

Southampton Airport (SOU): www.southamptonairport.com
Stockholm-Arlanda Airport (ARN): www.arlanda.se
Trondheim Airport (TRD): www.avinor.no
Zurich Airport (ZRH): www.zurich-airport.com

Airline and railway service operator websites:
Arriva Trains Wales (UK): www.arrivatrainswales.co.uk
AirFrance (France): www.airfrance.fr
CrossCountry (UK): www.crosscountrytrains.co.uk
DB Deutsche Bahn (Germany): www.bahn.com
DSB Danske Statsbaner (Denmark): www.dsb.dk
East Midlands Trains (UK): www.eastmidlandstrains.co.uk
First Capital Connect (UK): www.firstcapitalconnect.co.uk
First Great Western (UK): www.firstgreatwestern.co.uk
First ScotRail (UK): www.scotrail.co.uk
First Transpennine Express (UK): www.tpexpress.co.uk
Greater Anglia (UK): www.greateranglia.co.uk
London Midland (UK): www.londonmidland.com
Lufthansa (Germany): www.lufthansa.com
MAV Magyar Államvasutak (Hungary): www.mav.hu
NMBS/SNCB Société Nationale des Chemins de fer Belges (Belgium): www.belgianrail.be
Northen Rail (UK): www.northernrail.org
NS Nederlandse Spoorwegen (Netherlands) www.ns.nl
NSB Norges Statsbaner (Norway): www.nsb.no/
RENFE Red Nacional de los Ferrocarriles Españoles (Spain): www.renfe.es
SBB-CFF-FFS Chemins de fer fédéraux suisses (Switzerland): www.sbb.ch
SJ Statens Järnvägar (Sweden): www.sj.se
SNCF Société nationale des chemins de fer français (France): www.sncf.com
Southern (UK): www.southernrailway.com
South West Trains (UK): www.southwesttrains.co.uk
Thalys (Belgium, France, Netherlands, Germany): www.thalys.com
Trenitalia (Italy): www.trenitalia.com
UL Upplands Lokaltrafik (Sweden): www.ul.se
Virgin Trains (UK): www.virgintrains.co.uk

Railway infrastructure company websites:
ADIF Administrador de Infraestructuras Ferroviarias (Spain): www.adif.es
REFER Rede Ferroviária Nacional (Portugal): www.refer.pt
RFF Réseau ferré de France (France): www.rff.fr