

**EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION**



Airport intermodality indicators

CARE II: MODAIR: Measure and development of interMODality at AIRport

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Executive Summary

The study “MODAIR: Measurement of inter-modality at AIRport” aims at measuring airport inter-modality and determining how its development could impact airport catchments area, by elaborating a methodology as well as a software tool. The objective of the Work-Package 1 is to build indicators providing measures of air/rail inter-modality at airport.

These indicators have been grouped in four categories:

- Indicators of inter-modal infrastructure
- Indicators of inter-modal operators
- Indicators of inter-modal services
- Indicators of inter-modal demand

Inside these categories 4 to 8 different indicators have been defined with an aim to answer the objectives that have to be met. For each of these categories, indicators related to airport access have been differentiated from indicators of airport integration in the regional or national network of other transport modes. Each time it was possible, when difficulties have been identified for collecting the necessary data for computing the indicators, alternative indicators providing less accurate information than the first defined indicators but being more easily computable have also been defined.

Categories of indicators	Objectives of indicators	Proposed indicators		Alternative indicators	
		Airport access	Airport integration	Airport access	Airport integration
Inter-modal infrastructure	Existence of rail infrastructure in the airport area	Number of rail infrastructure connected to the airport		–	–
	Access time between the inter-modal infrastructure and the terminal	Access times between the airport railway station and the several terminals weighted by the proportion of passengers that can be handled in each terminal	Minimum connection time	Average of the different access times between the airport railway terminal and the airport terminals	–
	Rail capacity	Yearly capacity in number of passengers of the railway stations located in the airport area		–	–
	Interest of inter-modal infrastructure for airport users	Travel duration in number of days for which passengers would prefer to access the airport by rail than by using their private car	Number of cities that are served by train from the airport for a train journey time not exceeding 3 hours	–	–
Inter-modal operators	Number of inter-modal operators	Number of inter-modal air operators		–	–
		Number of inter-modal rail operators		–	–
		Number of non European airlines proposing inter-modal service		–	–
	Market share	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport		–	–

Table 1: Indicators of inter-modal infrastructure and inter-modal operators

Categories of indicators	Objectives of indicators	Proposed indicators		Alternative indicators		
		Airport access	Airport integration	Airport access	Airport integration	
– Inter-modal services	Existence of inter-modal agreements	Number of agreements		–	–	
	Specificities of inter-modal agreements	Number of characteristics of each agreement weighted by the yearly market share in ASKs of the airline operator summed up over all agreements		–	–	
	Inter-modal air supply	Number of inter-modal destinations by air relative to the total number of destinations		–	–	
		Number of daily air frequencies summed up over all inter-modal destinations		–	–	
	Inter-modal rail supply		Number of inter-modal rail destinations	–	–	
		Average daily frequencies of the airport rail access	Number of daily rail frequencies summed up over all inter-modal rail destinations		–	–
	Competition between air and rail		Number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air		–	–
		–	Number of daily frequencies by air on all competing routes, divided by the total number of daily frequencies (air+rail)		–	–
Demand for inter-modality	Number of inter-modal passengers transported	Number of passengers using inter-modal services relative to the number of passengers flying to or from the airport on flights where inter-modal agreements exist		Number of passengers using inter-modal services relative to the total number of airport passengers that are not in transit		
	Number of multimodal passengers transported	Number of passengers using successively rail and air (whether they benefit from an inter-modal agreement or not) relative to the number of passengers flying to or from the airport on flights where inter-modal agreements exist		Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit		
	Potential demand for inter-modal service with current service levels	Number of passengers of the airport that are not in transit	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	–	Population of the destination cities directly served by train from the airport	
	Potential demand for inter-modal 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 by air multiplied by the average number of trips each person makes	–	Population of all the rail destination cities that could be directly linked to the airport in a journey time inferior to 3 hours	

Table 2: Indicators of inter-modal service and demand for inter-modality

In order to allow a more synthetic view of these indicators we have decided to highlight the most relevant indicators, per category of indicators.

At the supply side, these “macro-level indicators” are the following:

- Inter-modal infrastructure:
 - the number of rail infrastructure connected to the airport;
- Inter-modal operators:
 - yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport;
- Inter-modal service:
 - Number of inter-modal destinations by air relative to the total number of destinations;
 - Average daily frequencies of the airport rail access;
 - Number of inter-modal rail destinations (airport integration).

At the demand side, the “macro-level indicator” is the following:

- Demand for inter-modality:
 - Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit.

This study therefore propose two levels of analysis of inter-modality at airport:

1. A macro-level analysis taking only in consideration the representative indicators and providing a broad picture
2. A detailed analysis taking all the indicators in consideration and allowing to confirm or mitigate the results obtained in the macro-level analysis

These two levels of analysis have been applied to four airports where inter-modal agreements exist. The considered airports are Paris CDG, Frankfurt, Amsterdam Schiphol and London Heathrow. Heathrow being the only airport where inter-modal agreements exist for airport access, it was not possible to compare airport access indicators of inter-modal services, operators and demand of this airport with other airport cases. Indicators of this airport have then been commented without being able to benchmark between airports (Table 3: Macro-level indicators of airport access).

	Category of indicators	Indicator	London Heathrow airport	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Supply	Inter-modal infrastructure	Number of rail infrastructure connected to the airport	2	1	1	1
	Inter-modal operators	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport	55%	0	0	0
	Inter-modal service	Number of inter-modal destinations by air relative to the total number of destinations	84%	0	0	0
		Average daily frequencies of the airport rail access	70	0	0	0
Demand	Demand for inter-modality	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	32%	Not available	Not available	Not available

Table 3: Macro-level indicators of airport access

Benchmarking between airports has been done in the case of airport integration for which we have

compared inter-modal indicators of Paris CDG, Frankfurt and Amsterdam Schiphol airports. (Table 4: Macro level indicators for airport integration)

When analysing macro-level indicators for airport access, only Heathrow proposes a certain level of inter-modal supply since the other airports do not yet benefit from any inter-modal agreement. On the other hand, the analysis of the macro-level indicators shows that Frankfurt appears to have the highest levels of supply and demand of inter-modality.

	Category of indicators	Indicator	London Heathrow airport	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Supply	Inter-modal infrastructure	Number of rail infrastructure connected to the airport	0	1	2	2
	Inter-modal operators	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport	0%	60%	88%	59%
	Inter-modal service	Number of inter-modal destinations by air relative to the total number of destinations	0%	58%	76%	58%
		Number of inter-modal destinations by rail	0	16	6000	6002
Demand	Demand for inter-modality	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	0%	5%	13%	Not available

Table 4: Macro level indicators for airport integration

The detailed analysis has in addition allowed to show that Frankfurt airport provides the best infrastructure indicators in terms of number of inter-modal infrastructures and of access time between the infrastructures, Paris CDG airport offers a high level of interest for airport users in terms of available rail destinations. The good performance of Frankfurt airport is also tangible in terms of inter-modal services since inter-modal agreements existing at this airport provide better levels of inter-modal services than at Paris CDG or Amsterdam Schiphol airport. If inter-modal services offered at Paris CDG airport seems to be better than at Amsterdam Schiphol airport in terms of number and specificities of inter-modal agreements, they are no as good in terms of inter-modal rail supply.

As a consequence, the detailed analysis of the indicators tends to confirm the good level of inter-modality at Frankfurt airport already shown by the macro-level analysis. This detailed analysis indeed help to check that this good level generally exists when considering all the aspects of inter-modality that can be measured.

Indicators of airport inter-modality have been defined so as to provide the most accurate information as possible in order to evaluate the level of inter-modality at the airport as well as to compare the level of inter-modality of different airports. Nevertheless, an efficient use of them would require collecting all the necessary data while some of them are not public. This gap of data remains the main obstacle to the use of all these indicators as measures of inter-modality levels.

Acronyms

AEEL	Aviation Economics and Econometrics Laboratory
ANA	Aeroportos de Portugal, SA
ASK	Available Seat Km
ATC	Air Traffic Control
ATM	Air Traffic Management
CARE	Co-operative Actions of R&D in EUROCONTROL
CDG	Charles de Gaulle
ENAC	Ecole Nationale de l'Aviation Civile
HSR	High Speed Rail
HST	High Speed Train
MODAIR	Measure and development of inter-modality at AIRport
N/A	Non Available
RATP	Régie Autonome des Transports Parisiens
RFF	Réseau Ferré de France
SNCF	Société Nationale des Chemins de Fer
TGV	Train à Grande Vitesse
WP	Work-Package

Websites

Information on the values used for computing the indicators have been taken from the following websites:

- **General information on inter-modal airports and on inter-modal agreements:**

<http://www.frankfurt-airport.com>
<http://www.adp.fr>
<http://www.schiphol.nl>
<http://www.heathrowairport.com>
<http://www.lufthansa.com>
<http://www.airfrance.fr>
<http://www.air-austral.com>
<http://www.airtahitinui.com>
<http://www.aa.com>
<http://www.continental.com>
<http://www.qatarairways.com>
<http://www.cathaypacific.com>
<http://www.klm.com>
<http://www.united.fr>
<http://www.delta.com>
<http://www.thalys.com>
<http://www.tgv.com>
<http://www.ratp.com>
<http://www.bahn.de>

- **Minimum connecting times figures:**

<http://www.parliament.uk/documents/upload/TransportAP03.pdf>;
http://www.I.iata.org/WHIP/Files/WgId_0061/Inter-modal%20Final%20Report.pdf;
http://www.britishairways.com/travel/askbainter/public/en_gb?p_search_text=mct;
<http://www.airfrance.fr>
<http://www.klm.com>
<http://www.emirates.com/in/TravellerInformation/arrival/FrenchRailways/FrenchRailways.asp?ComponentID=4031&SourcePageID=1922>

- **Cost of the transport modes connecting the airport:**

<http://www.voyages-sncf.com>; <http://www.ns.nl>; <http://www.bahn.de>;
<http://www.heathrowexpress.com>;
[http://www.latribune.fr/Dossiers/cahierauto2004.nsf/\(LookupPrint\)/ID0A8FE86EE460D06AC1256F150056CA73?OpenDocument](http://www.latribune.fr/Dossiers/cahierauto2004.nsf/(LookupPrint)/ID0A8FE86EE460D06AC1256F150056CA73?OpenDocument);

- **Terminals capacity figures:**

<http://www.assemblee-nationale.fr/12/rap-info/i1016-2.asp>; http://europa.eu.int/eur-lex/pri/en/oj/dat/1998/l_072/l_07219980311en00300050.pdf

- **Access times to the airport per transport mode:**

<http://www.airwise.com/airports/europe/FRA/>;
<http://www.airwise.com/airports/europe/AMS/index.html>;
<http://www.toandfrom.org/airport/heathrow.html>;
http://www.debatpublic-cdgexpress.org/docs/pdf/partie_1-3.pdf

<http://www.ratp.fr> ;
http://journeyplanner.tfl.gov.uk/user/XSLT_TRIP_REQUEST2?language=en;
<http://www.airport-connection.com/faq-fr.html>

- **Inter-modal destinations figures (percentage of the population that travels yearly by air, average number of trips per person):**

http://www.aviation-civile.gouv.fr/html/prospace/stats/pdf_sdeep/synth14.pdf

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1 Introduction

1.1 Scope of the study

In a context of a fast evolution of the air transport market, the future of the Air Traffic Management will not only be linked to the improvements in technologies, but also to the evolution of traffic flows. Despite the current difficulties in air transport, forecasts still mention strong traffic increases for years to come. One of the main solutions chosen by the European Commission for coping with airport congestion problem and transports' pollution is to develop inter-modal transports to air. This development is an important objective of the European Commission since inter-modality and multimodality are at the heart of the 2001 European Commission white papers on transport [Ref 2]. One of the main priority objectives to be attained by 2010 is to link-up transport modes for successful inter-modality.

As shown by the study "The Airport of the future: Central link of inter-modal transports?", there are numerous lacks in the existing studies relative to inter-modality at airports. In particular, there is no proposed way for measuring inter-modality and no study determining what could be the development of inter-modality at airports. In addition, if airport inter-modality is often considered as a way to increase airport catchment area and ease air congestion, no specific studies have already been made on these subjects.

The study "MODAIR: Measure and development of inter-modality at AIRport" aims at filling part of these lacks by elaborating a methodology as well as a software tool aiming at measuring airport inter-modality and evaluating how a development in inter-modality could impact airport catchments areas.

Inter-modality is the characteristic of a transport network and associated services, which allows the combined use of at least two different transport modes for at least one single trip from origin destination. In literature, the term "inter-modal" transport applied to passengers using successively air and other transport modes is used equally for the airport access to the city centre or for the integration of the airport in the regional or national network of other transport modes. As the implications of both types of airport inter-modality are different in terms of transport policies, investment, passenger needs, operators coordination, etc., we have chosen in this study to differentiate between them. In the case of airport access, the relevant modes to study are road and rail public transport modes. In the case of integration of the airport in the regional or national network, only rail is relevant (and particularly high speed train), since bus services on long distances are quite rare in Europe, and do not seem to become more prominent in the future since buses do not compete in terms of speed with rail or air. Conversely, air/rail inter-modality seems to offer promising opportunities for the future.

Notes:

- The present study is passenger-oriented and freight was not considered within its scope. Although freight movement is highly important within the trans-European transport networks its inter-modality is driven by a different set of specialities that would require a specific study.
- It should be noted that in the time available, it has been possible to analyse rail-air inter-modality only. We have decided to focus on rail-air as this type of inter-modality is becoming more and more prominent with the opening – in particular – of dedicated high speed links with city centres (Heathrow Express, project at Paris CDG for the construction of CDG Express, etc.). Moreover, the analysis of bus-air inter-modality would require a full study on its own since the features of such type of inter-modality are quite different from rail-air inter-modality.

1.2 Scope of the document

The objective of this work package is to build indicators providing a concrete measurement of inter-modality at airport.

These indicators will be defined in section 2 where indicators related to airport access will be differentiated from indicators of airport integration in the regional or national network of other transport modes.

Section 3 will then study the role and the relative importance of the indicators identified in section 2 in order to allow to obtain a more synthetic view of the indicators.

Section 4 presents four airports on which indicators of airport inter-modality will be computed and compared in section 5.

This report will then end by concluding remarks provided in section 6.

1.3 References

- [Ref 1] COMMISSARIAT GENERAL AU PLAN “Transports pour un meilleur choix des investissements”, Groupe présidé par Marcel Boiteux, November 1994
- [Ref 2] EUROPEAN COMMISSION “White Paper, European transport policy for 2010: time to decide” European Communities, 2001
- [Ref 3] GROUPE DE TRAVAIL GUYARD “Multimodalité Avion-TGV », July 2004
- [Ref 4] HEATHROW ASSOCIATION FOR THE CONTROL OF AIRCRAFT NOISE “The growth in transfer and transit passengers at Heathrow between 1992 and 2004”, May 2005
- [Ref 5] IATA/ACI/ATAG "Airport Capacity/Demand Profiles", Airports Council International, Air Transport Action Group, International Air Transport Association, 2003 Edition
- [Ref 6] LAPLACE I., N. LENOIR, F. PITA, I. REBELLO, A. VALADARES, 2004, “WP1 - Review of the current inter-modality situation”, EUROCONTROL CARE INO project: “The airport of the future: Central link of inter-modal transport?”, M3 SYSTEMS, ANA, ENAC-AEEL October 2004
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- [Ref 9] MACDONALD M., 2003, “Key European hubs: Comparison of aviation policy”, Transport Committee, May 2003

2 Indicators of airport inter-modality

Airport inter-modality is relative to the use of collective transport different from air transport for coming to and from the airport in an integrated way. Inter-modality at airport can therefore concern:

- Airport access: access to/from the airport from/to the city centre;
- Airport integration: feeding of airport flights with other transport modes than air (either regional or high-speed trains).

By producing a state of the art of airport inter-modality, the work-package 1 of the study “The airport of the future: Central link of inter-modal transports” has provided important information on inter-modality features in operational, financial, politic terms. In particular, the analysis of the current inter-modality at airport has allowed highlighting the existence of different types of airport inter-modality with different features. In addition, the presentation of the current application of inter-modality at airports has allowed identifying that different cooperation agreements between operators lead to different levels of inter-modality.

Measuring inter-modality leads to evaluate these levels of inter-modality by considering both supply and demand sides of the inter-modal transportation, i.e:

- With regards to the supply of inter-modal transportation:
 - The infrastructure of other transport modes than air that are connected to the considered airport;
 - the airport transport operators offering inter-modal services;
 - the services proposed by transport operators in the scope of inter-modal agreements at the airport;
- Concerning the demand to the inter-modal transportation:
 - the passenger demand to these services.

As a consequence, we propose to distinguish four categories of indicators:

- **Indicators of inter-modal infrastructure;**
- **Indicators of inter-modal operators;**
- **Indicators of inter-modal services;**
- **Indicators of inter-modal demand.**

After having defined which objectives have to be met in each category of indicator, we will define the “ideal” indicators answering these objectives. The identification of the data necessary for computing these indicators and of their availability will then allow us to determine what could be the difficulties for computing these “ideal” indicators. In case an “ideal” indicator could be difficult to compute due to gap of data, we propose an alternative indicator that could be computed with easily available data, but providing less accurate information.

For each of these categories, indicators related to airport access will be differentiated from indicators of airport integration in the regional, national or trans-national network of other transport modes.

Theoretically, inter-modal transport to air can be rail or bus transport. However, as already mentioned before (see § 1.1, scope of the study), considering the air/bus inter-modality would require to perform a full study on this type of inter-modality that would be worth to be done in further works. We will therefore focus in the MODAIR study on air/rail inter-modality that is the most common type of inter-

modality for passenger transportation. That is why we have chosen to not consider road access as inter-modal infrastructure.

2.1 Indicators of inter-modal infrastructure

2.1.1 Objectives

The objective of indicators of inter-modal infrastructure is to describe rail and road infrastructure connected to the airport for airport access or airport integration in the global rail network (HSR or conventional rail). At this point we are not concerned with the existence or non-existence of actual inter-modal agreements using these infrastructures but only with the potential for such agreements.

The first indicator has to relate to the **existence of rail infrastructure in the airport area**. In addition, we consider that for an infrastructure to be efficiently used for inter-modality, it is essential that this infrastructure belongs to the airport area, simply because infrastructure outside the airport area is generally too long to access.

A second requirement is that the access time between this infrastructure and the terminal has to be short enough. **Measuring this access time** is the objective of the second indicator.

Thirdly, we need to **measure the capacity of railway station**. This is the objective of a third indicator.

Finally we will deal with **the interest of this infrastructure for airport users**. For airport access this interest of airport users will concern the comparison of the generalised cost of transport by rail access and by private car. For airport integration, connecting to a HSR network is different from connecting to a conventional network. However, in both cases, the interest of using rail depends on the possibilities rail offers in terms of destinations that can be reached in a reasonable time.

2.1.2 Proposed indicators

2.1.2.1 Existence of rail infrastructure in the airport area

As indicator answering this objective we propose to consider the **number of rail infrastructure connected to the airport**.

For airport access, we will take into account airport dedicated rail link infrastructure, light rail link infrastructure, subway infrastructure and suburban rail link infrastructure.

For airport integration, we will take into account regional rail link infrastructure and high-speed rail link infrastructure.

Ex : If an airport is connected to subway, dedicated rail link and high-speed rail network, the value of the indicator of existence of rail infrastructure will be:

- *Indicator=2 for airport access, and*
- *Indicator=1 for airport integration.*

Summary:

$$\text{Airport access indicator} = \sum_{i=1}^n I_i$$

Where I_i is the rail infrastructure i allowing the airport access from the city centre

$$\text{Airport integration indicator} = \sum_{j=1}^m I_j$$

Where I_j is the rail infrastructure j allowing the integration of the airport in a regional or national rail network

2.1.2.2 Measure of the access time between the inter-modal infrastructure and the terminal

Concerning airport integration, as indicator answering this objective, we propose to consider the **minimum connection time (in minutes)** between rail and air transport.

Ex : The airport integration indicator of the measure of the access time on a specific airport is 45 minutes meaning that airlines recommend at least 45 minutes between the train arrival and the flight departure. The indicator of the minimum connection time will be:

- Indicator = 45 for airport integration

Concerning airport access, the measure of the access time depends on the access time between the airport railway station and each terminal. That is why we propose to build the indicator by **weighing these access times between the airport railway station and the several terminals with the proportion of passengers that can be handled in each terminal (terminal capacity)**. If several railway stations exist at the considered airport we weigh these access times with regards to the sharing of passengers among the several rail airport accesses.

Ex : The considered airport has two terminals. If the time for getting to the Terminal 1 from the airport railway station is 10 minutes while the time for getting to the Terminal 2 is 5 minutes, and if 55% of air passengers use Terminal 1 and 45% use Terminal 2 the indicator of the measure of the access time will be:

- Indicator = $55\% * 10 + 45\% * 5 = 7.75$ minutes for airport access

Nevertheless the proportion of air passengers according to the different airport terminals can be difficult to obtain. In this case, we propose an **alternative indicator for the access time consisting in computing the average of the different access time between the airport railway terminal and the airport terminals**.

Ex : In the example considered above, the alternative indicator of the access time will be:

- Indicator = $(10+5)/2 = 7.5$ minutes for airport access

Summary:

$$\text{Airport access indicator} = \sum_{j=1}^m S_j \times \left(\sum_{i=1}^n P_i A_{ij} \right)$$

Where:

S_j is the proportion of passengers accessing the airport by rail that use railway station j

P_i is the proportion of passengers that can be handled in terminal i

A_{ij} is the access time in minutes between the railway station j and the terminal i

$$\text{Alternative airport access time indicator} = \sum_{j=1}^m S_j \times \frac{\left(\sum_{i=1}^n A_{ij} \right)}{n}$$

Where:

S_j is the proportion of passengers accessing the airport by rail that use railway station j

A_{ij} is the access time in minutes between the railway station j and the terminal I

n is the number of airport terminals

$$\text{Airport integration indicator} = MCT$$

Where MCT is the minimum connection time in minutes between rail and air transport modes

2.1.2.3 Rail capacity

For measuring the rail capacity we propose to consider as indicator the **annual capacity in number of passengers of the railway stations located in the airport area**. When several railway stations exist at the considered airport for airport access (for instance one underground station and one station for airport dedicated rail link) or for airport integration (for instance one railway station for regional trains and one railway station for high-speed trains), we will add the annual capacity of these stations.

Ex : Suppose that an airport has one underground station, one station for airport dedicated rail link, one railway station for regional trains and one railway station for high-speed train. If the yearly capacity of the underground station is 3 millions of passengers, the yearly capacity of the dedicated rail link station is 2.5 millions of passengers, the yearly capacity of the regional trains station is 5 millions passengers and the yearly capacity of the high-speed trains station is 4 millions of passengers, the value of the indicator of railway stations capacity will be:

- *Indicator = 3 000 000+2 500 000=5 500 000 for airport access*
- *Indicator = 5 000 000+ 4 000 000=9 000 000 for airport integration*

Summary:

$$\text{Airport access indicator of railway stations capacity} = \sum_{i=1}^n C_i$$

Where C_i is the yearly capacity in number of passengers of the railway station i allowing the airport access from the city centre. n is the number of railway stations at the airport access from the city centre.

$$\text{Airport integration indicator of railway stations capacity} = \sum_{j=1}^m C_j$$

Where C_j is the yearly capacity in number of passengers of the railway station j allowing the integration of the airport in a regional or national rail network. m is the number of railway stations at the airport allowing the integration of the airport in a regional or national rail network.

2.1.2.4 Measure of the interest of inter-modal infrastructure for airport users

Measuring the interest for airport users to use the rail infrastructure, as opposed to road, for accessing airport or for connecting flights would require a modal choice model taking into account the passenger's and journey features, as well as the journey time and price. The building of this modal choice would exceed the scope of our study. We however propose to provide some answer elements by building indicators taking into account the journey's time and price.

The proposed indicator for airport access aims at determining for which travel duration in number of days, passengers would prefer to access the airport by rail than by using their private car, based on a "all-or-nothing" minimum generalized cost approach. For this we will compute a generalised cost for the rail access (round trip) including the rail journey price (P_R), the rail access time (T_R) in minutes (see first indicator for airport access) and the value of time for passengers using rail (V_R) (that can be averaged according to the proportion of passengers by purpose of travel (leisure or business), that use the airport. In the case where several rail access exist at the airport we compute the generalised costs of each rail access and weigh them with the proportion of passengers accessing the airport by rail that use each rail access (P_i).

$$Rail\ Cost = \sum_{i=1}^n P_i \times (P_R + T_R \times V_R) \times 2$$

We will then compare this cost with the generalised cost for the access by car (round trip) including the distance in kilometres between the city centre and the airport (D_C), the price per kilometre for using the car (P_C), the time in minutes for accessing the airport by car (T_C) (without congestion), the congestion factor for road access than multiplies T_C (C), the passenger value of time by car (V_C), the daily price of airport parking (P_p) and the number of day the car is parked at the airport (D_T) (i.e. the travel duration).

C takes the following values:

- 1 if the typical variation in access time, congestion or non congestion, is less then 15 minutes (ex: typical time access is 20-30 minutes);
- 1,2 if the typical variation in time access, congestion or non congestion, is less then 45 minutes (ex: typical time access is 45-70 minutes);
- 1,5 if the typical variation in time access, congestion or non congestion, is equal or greater then 45 minutes (ex: typical time access is 40-90 minutes).

Note:

The defined values for C are based on the assumption that C is all the more high given that the time variation for accessing the airport by road is high. At this time, no studies that deal with the subject have been found. In order to get more accurate values for C , empirical validation should thus been made in further works.

$$Road\ Cost = (P_C \times D_C + T_C \times C \times V_C) \times 2 + (P_p \times D_T)$$

The indicator of the interest of rail infrastructure will be the value D_T such as the road cost exceeds

the rail cost i.e. the value D_T such as:

$$(P_C \times D_C + T_C \times C \times V_C) \times 2 + (P_P \times D_T) \geq \sum_{i=1}^n P_i \times (P_R + T_R \times V_R) \times 2$$

Ex : Suppose that accessing the airport by rail costs 20 euros for 20 minutes of access time and that the passenger value of time is 1 euro per minute (by rail as well as by car). Suppose also that the price per kilometre for accessing the airport by car is 0.30 euros for 20 kilometres performed in 25 minutes and that the daily price of airport parking is 18 euros. Suppose also that the typical variation in the time access by road due to congestion is 10 minutes. The indicator of travel duration from which rail access is preferred to road access is:

$$D_T = \frac{\sum_{i=1}^n P_i \times (P_R + T_R \times V_R) \times 2 - (P_C \times D_C + T_C \times C \times V_C) \times 2}{P_P}$$

- *Indicator = $D_T = (20 + 20 \times 1 - 0.30 \times 20 - 25 \times 1 \times 1) \times \frac{2}{18} = 1$ day for airport access meaning that for a travel duration (round trip) exceeding one day rail is preferred to private car*

The proposed indicator for measuring the interest of inter-modal infrastructure for airport users in the case of airport integration is the **number of cities that are served by train from the airport for a train journey time not exceeding 3 hours**.

Ex : If 10 cities can be reached by train from the airport in less than 3 hours, the indicator of interest of inter-modal infrastructure for airport users will be:

- *Indicator = 10 for airport integration*

Summary:

$$\text{Airport Access indicator} = D_T = \frac{\sum_{i=1}^n P_i \times (P_R + T_R \times V_R) \times 2 - (P_C \times D_C + T_C \times C \times V_C) \times 2}{P_P}$$

Where:

P_R is the rail journey price

T_R is the rail access time

V_R is the value of time for passengers using rail

P_i is the proportion of passengers accessing the airport by rail that use each rail access

D_C is the distance in kilometres between the city centre and the airport

P_C is the price per kilometre for using the car

T_C is the time in minutes for accessing the airport by car

C is the congestion factor for road access

V_C is the passenger value of time by car

P_P is the daily price of airport parking

$$\text{Airport integration indicator} = \sum_{j=1}^m \text{City}_j$$

Where City_j is a city served by train from the airport for a train journey time not exceeding 3 hours

2.2 Indicators of inter-modal operators

2.2.1 Objectives

We look at the inter-modal operators : **do they exist?**, **how many air operators have inter-modal agreements?**, what is **their market share on the airport?**, **How many rail operators participate in inter-modal agreements?** The same indicators will apply here to airport access and airport integration (but possibly with different figures, since operators may be different in both cases).

2.2.2 Proposed indicators

2.2.2.1 Number of inter-modal operators

We compute the **number of inter-modal air operators** and the **number of inter-modal rail operators**. In general the second one will take values 0 to 2, while the first one can be quite higher.

Ex : Suppose the airport is connected to a dedicated rail link operated by a single rail operator having concluding inter-modal agreements with 5 airlines. Suppose also that this airport has connection with high-speed rail links operated by two different rail operators, where one rail HSR operator has concluded inter-modal agreements with 10 different airlines whose three of them have concluded another inter-modal agreements with the second HSR operator.

The indicator of the number of inter-modal air operators will be:

- *Indicator = 5 for airport access*
- *Indicator = 10 for airport integration*

The indicator of the number of inter-modal rail operators will be:

- *Indicator = 1 for airport access*
- *Indicator = 2 for airport integration*

It is also interesting to see if inter-modality is a typically European phenomenon or if non-European airlines propose this kind of service. The indicator would be the **number of non-European airlines proposing inter-modal service**.

Ex.: Suppose that among the 5 air operators having concluded inter-modal agreements for airport access 2 of them are non-European. Suppose also that among the 10 air operators having concluded inter-modal agreement in the scope of airport integration 5 of them are non-European. The indicator of the number of non-European airlines proposing inter-modal service will be:

- *Indicator = 2 for airport access*
- *Indicator = 5 for airport integration*

Summary:

$$\text{Airport access indicator of the number of inter-modal air operators} = \sum_{i=1}^n Eur_i + \sum_{j=1}^m NonEur_j$$

Where

Eur_i is the European airline i having concluded at least one inter-modal agreement for airport access at the airport

$NonEur_j$ is the non-European airline j having concluded at least one inter-modal agreement for airport access at the airport

$$\text{Airport access indicator of the number of inter-modal rail operators} = \sum_{k=1}^o Rail_k$$

Where

$Rail_k$ is the rail operator k having concluded at least one inter-modal agreement for airport access at the airport

$$\text{Airport access indicator of the number of non-European inter-modal air operators} = \sum_{j=1}^m NonEur_j$$

Where

$NonEur_j$ is the non-European airline j having concluded at least one inter-modal agreement for airport access at the airport

$$\text{Airport integration indicator of the number of inter-modal air operators} = \sum_{k=1}^o Eur_k + \sum_{l=1}^p NonEur_l$$

Where

Eur_k is the European airline k having concluded at least one inter-modal agreement for airport integration at the airport

$NonEur_l$ is the non-European airline l having concluded at least one inter-modal agreement for airport integration at the airport

$$\text{Airport integration indicator of the number of inter-modal rail operators} = \sum_{m=1}^q Rail_m$$

Where

$Rail_m$ is the rail operator m having concluded at least one inter-modal agreement for airport integration at the airport

$$\text{Airport integration indicator of the number of non-European inter-modal air operators} =$$

$$\sum_{l=1}^p NonEur_l$$

Where

$NonEur_l$ is the non-European airline l having concluded at least one inter-modal agreement for airport integration at the airport

2.2.2.2 Market Share

The market share indicator is defined as the **share of yearly Available-Seat-kilometres of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport.**

Ex.: Suppose that the 5 air operators having concluded inter-modal agreements for airport access represent a market share in ASKs of 40% on the airport while the 10 air operators having concluded inter-modal agreement in the scope of airport integration represent a market share in ASKs of 50%. The indicator of the market share on the airport, in terms of Passengers-Kilometre Transported will be:

- *Indicator = 40% for airport access*
- *Indicator = 50% for airport integration*

Summary:

$$\text{Airport access indicator} = \sum_{i=1}^n ASK_i$$

Where

ASK_i is the market's share of the inter-modal airline i (i.e. the airline i having concluded at least one inter-modal agreement for airport access at the airport) in terms of available-seat-kilometres.

$$\text{Airport integration indicator} = \sum_{k=1}^o ASK_k$$

Where

ASK_k is the market's share of the inter-modal airline k (i.e. the airline k having concluded at least one inter-modal agreement for airport integration at the airport) in terms of available-seat kilometres.

2.3 Indicators of inter-modal services

2.3.1 Objectives

The objectives of indicators of inter-modal services are to identify and analyse inter-modal services based on operator's inter-modal agreements.

At this point we look at inter-modal agreements, and what are their characteristics in terms of services for passengers.

The first two indicators relate to the **existence of inter-modal agreements** and **what they represent in terms of supply at the airport.**

Then we turn to the **specificities of the agreements.** Inter-modal agreements can have several features: global reservation, global check-in with luggage, global check-in without luggage, single ticketing, etc.

Besides their cooperation in the scope of inter-modal agreements, rail and air operators can still remain competitors on some routes. That is why we will also **measure this competition**.

It would also be interesting to build indicators on qualitative aspects of inter-modal services, as for instance relative to:

- The signs of inter-modal services (at the airport, at the railway terminal, inside trains, etc.);
- The various possibilities of trip reservation (travel agency, internet, etc.);
- The availability of information on such inter-modal services;
- The publicity on these inter-modal services (on internet, newspaper, television, etc.);
- Etc.

Unfortunately these qualitative aspects can be very difficult to measure at the current state of development of airport inter-modality. That is why we will not propose qualitative indicators of inter-modal services and will focus on quantitative indicators.

2.3.2 Proposed indicators

2.3.2.1 Existence of inter-modal agreements

In order to relate the existence of inter-modal agreements we propose to consider the **number of inter-modal agreements** by couple of air and ground operators.

Ex : If one airline has concluded an inter-modal agreement with the operator of the dedicated rail link connected to the airport and if this same airline as well as two other airlines have concluded an inter-modal agreements with the high-speed rail operator, the value of the indicator of existence of inter-modal agreement will be:

- *Indicator=1 for airport access, and*
- *Indicator=3 for airport integration*

Summary:

$$\text{Airport access indicator} = \sum_{i=1}^n \sum_{j=1}^m Ag_{ij}$$

Where Ag_{ij} is the inter-modal agreement concluded between the rail operator i and the airline j , in the scope of airport access

$$\text{Airport integration indicator} = \sum_{k=1}^o \sum_{l=1}^p Ag_{kl}$$

Where Ag_{kl} is the inter-modal agreement concluded between the rail operator k and the airline l , in the scope of airport integration

2.3.2.2 Specificities of inter-modal agreements

Inter-modal agreements can have the following features:

- Global reservation for the whole trip (air and ground journeys);
- Single ticket for the whole trip meaning that the traveller has not to exchange a flight coupon for a rail boarding pass;
- Global check-in with hand luggage;
- Global check-in with luggage;
- Global check-in with hand luggage the day before the flight;
- Global check-in with luggage the day before the flight.

These specificities have different values to the passenger and some might be less relevant decision making tools than others. If the indicator should take into account these different values by weighting these specificities, information on these weighting are missing. Hence, if future work would be worth to be done in this domain for being able to compute a weighted indicator, we will consider the same weight for all specificities.

The proposed indicator is therefore the **number of characteristics of each agreement weighted by the yearly market share in ASKs of the airline operator summed up over all agreements.**

Ex : Airline A has concluded an inter-modal agreement for airport access allowing a global reservation for the whole trip and a single ticketing. The number of features of inter-modal agreement for airport access is therefore 2. This same airline has also concluded an inter-modal agreement for airport integration allowing the global reservation, the global check-in with hand luggage, the global check-in with luggage. The number of features of inter-modal agreement for airport integration is therefore 3. The Airline A's market share in ASKs at the airport is 40%.

Airline B has concluded an inter-modal agreement for airport integration with the same features than the agreement concluded by Airline A. The number of features of inter-modal agreement for airport integration is therefore 3. The Airline B's market share in ASKs at the airport is 5%

Airline C has concluded an inter-modal agreement for airport integration allowing a global reservation for the whole trip, the global check-in with hand luggage, the global check-in with luggage and a single ticket for the whole trip. The number of features of inter-modal agreement for airport integration is therefore 4. The Airline C's market share in ASKs at the airport is 15%.

In this situation, the indicator of specificities of inter-modal agreements will be:

- *Indicator = 40%*2 for airport access*
- *Indicator = 40%*3+5%*3+15%*4 for airport integration*

Summary:

$$\text{Airport access indicator} = \sum_{i=1}^n \sum_{j=1}^m Sp_{ij} \times ASK_j$$

Where

Sp_{ij} is the number of specificities of the inter-modal agreement concluded between the rail operator i and the airline j , in the scope of airport access

ASK_j is the yearly market in Available Seat Kilometres of airline j at the airport

$$\text{Airport integration indicator} = \sum_{k=1}^o \sum_{l=1}^p Sp_{kl} \times ASK_l$$

Where

Sp_{kl} is the number of specificities of the inter-modal agreement concluded between the rail operator k and the airline l , in the scope of airport integration

ASK_l is the yearly market in Available Seat Kilometres of airline l at the airport

2.3.2.3 Inter-modal air supply

We need to look at the air destinations offered with inter-modal agreements, and also at the frequency of service.

The first indicator computed could be the **number of inter-modal air destinations relative to the total number of air destinations** that can be reached from the airport.

Ex : If there are 2000 air destinations proposed from the airport and if all of them are proposed in the scope of air/rail inter-modal agreement for airport access while 1500 of them are proposed in the scope of air/rail inter-modal agreements for airport integration, the indicators of inter-modal destinations relative to the total number of destinations will be:

- *Indicator = 2000/2000=1 for airport access*
- *Indicator = 1500/2000=0.75 for airport integration*

The second indicator relative to inter-modal air supply could be the **number of frequencies summed up over all inter-modal air destinations**

Ex : Suppose that 5 air destinations are proposed in the scope of inter-modal agreements for airport access with 5 flights per day for 2 of them and 7 flights per day for the three other;

Suppose that 10 destinations are proposed in the scope of inter-modal agreements for airport integration with 6 flights per day for 6 of them, 4 flights per day for three of them and 3 flights per day for the last one.

The indicators of inter-modal destinations relative to the number of frequencies summed up over all inter-modal destinations will be:

- *Indicator = 2*5+3*7 for airport access*
- *Indicator = 4*6+3*4+1*3 for airport integration*

Summary:

$$\text{Airport access indicator of the number of inter-modal air destinations} = \frac{\sum_{j=1}^m Dest_j}{D_{Air}}$$

Where

$Dest_j$ is the total number of destinations proposed by airline j in the scope of all the inter-modal agreement for airport access it has concluded at the airport

D_{Air} is the total number of destinations offered by all airlines operating at the airport

$$\text{Airport access indicator of the frequencies of inter-modal air destinations} = \sum_{j=1}^m \sum_{r=1}^q Freq_{rj}$$

Where

$Freq_{rj}$ is the number of daily frequencies (going and returning flights) on the inter-modal air destination r proposed by airline j in the scope of all the inter-modal agreement for airport access it has concluded at the airport

$$\text{Airport integration indicator of the number of inter-modal air destinations} = \frac{\sum_{l=1}^p Dest_l}{D_{Air}}$$

Where

$Dest_l$ is the total number of destinations proposed by airline l in the scope of all the inter-modal agreement for airport integration it has concluded at the airport

D_{Air} is the total number of destinations offered by all airlines operating at the airport

$$\text{Airport integration indicator of the frequencies of inter-modal air destinations} = \sum_{l=1}^p \sum_{s=1}^r Freq_{sl}$$

Where

$Freq_{sl}$ is the number of daily frequencies (going and returning flights) on the inter-modal air destination s proposed by airline l in the scope of all the inter-modal agreement for airport integration it has concluded at the airport

2.3.2.4 Inter-modal rail supply

In the same way, we look in the scope of airport integration at the possible inter-modal destinations by rail, as well as their frequency.

The first indicator computed could be the **number of inter-modal rail destinations** that can be reached from the airport.

Ex : Suppose that the airport is connected to 4 different city railway stations thanks to a high-speed rail network. The indicator of the number of inter-modal rail destinations will be:

- *Indicator = 4 for airport integration*

The second one could be the **number of frequencies summed up over all inter-modal rail destinations**

Ex : Suppose that the airport is connected to 4 different city railway stations thanks to a high-speed rail network and that two of these city railway stations are served by 5 trains a day, one is served by 3 trains a day and one by 6 trains a day. The indicator of the number of frequencies summed up over all inter-modal rail destinations will be:

- *Indicator = 2*5+1*3+1*6 for airport integration*

Things are different for airport access since rail destinations are in this case not relevant for computing indicators of inter-modal rail supply. We therefore propose only one indicator for airport access relative to the **daily frequencies of the airport rail access**. When several rail accesses are included in inter-modal agreements, we weigh the frequency of each rail access by the proportion of passengers accessing the airport by rail and using this rail access.

Ex : Suppose that there are inter-modal agreements between the operator of the airport dedicated rail link and airlines operating at the airport. If there are each day 60 trains come/go to and from the airport, the indicator of inter-modal rail supply will be:

- *Indicator = 60 for airport access*

Summary:

$$\text{Airport access indicator of the frequencies of the airport rail accesses} = \sum_{i=1}^n \sum_{k=1}^s Freq_{ki} \times S_k$$

Where

$Freq_{ij}$ is the number of daily frequencies (going and returning trains) on the inter-modal rail access r proposed by the rail operator i in the scope of all the inter-modal agreement for airport access it has concluded at the airport

S_k is the proportion of passengers accessing the airport by rail and using the rail access k

$$\text{Airport integration indicator of the number of inter-modal rail destinations} = \sum_{k=1}^o Dest_k$$

Where

$Dest_k$ is the total number of destinations proposed by the rail operator k in the scope of all the inter-modal agreement for airport integration it has concluded at the airport

$$\text{Airport integration indicator of the frequencies of inter-modal rail destinations} = \sum_{k=1}^o \sum_{l=1}^u Freq_{lk}$$

Where

$Freq_{lk}$ is the number of daily frequencies (going and returning trains) on the inter-modal rail destinations proposed by rail operator k in the scope of all the inter-modal agreement for airport integration it has concluded at the airport

2.3.2.5 Competition between air and rail

We are interested here in the situation of competition today between air and rail on inter-modal routes. As the competition between rail and air only exists in the case of airport integration, proposed indicators only concern airport integration.

Different things can be measured in terms of supply: we can measure the **number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air** (example : Roissy-Lyon by TGV Air, or Roissy –Lyon by Air France). We will only take into account the competing destinations where the train journey time does not exceed 3 hours, assuming that above this time limit rail is no more competitive compared to air.

Ex : Suppose that the airport is connected to 4 different city railway stations thanks to a high-speed rail network and that 3 of these rail destinations are in competition with air service. More precisely if the airport is connected to city A, city B, city C and city D by rail and if there are flight between this

airport and airports of cities A, B, C, the indicator of the number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air will be:

- Indicator = 3 for airport integration

We can also measure the seats offered by both modes on these destinations, or the frequencies offered. Since operators compete by offering frequent service on a route, we propose to measure **the number of daily frequencies by rail on all competing routes, divided by the total number of daily frequencies (air+rail).**

Ex : Suppose that among the three competing routes between air and rail, two are served by 5 trains a day and by 4 flights a day while the last one is served by 4 trains a day and 5 flights, the indicator of the number of daily frequencies by air on all competing routes, divided by the total number of daily frequencies will be:

- Indicator = $(5+5+4)/(5+5+4+4+4+5)=14/27$ for airport integration

Summary:

$$\text{Airport integration indicator of the number of competing destinations} = \sum_{i=1}^n \sum_{j=1}^m \text{Comp}_{ij}$$

Where

Comp_{ij} is the number of destinations offered by the rail operator i in the scope of an inter-modal agreement where there is also a service by air offered by airline j

$$\text{Airport integration indicator of the frequencies of competing destinations} =$$

$$\frac{\sum_{k=1}^o \sum_{i=1}^n \text{FComp}_{ki}}{\sum_{k=1}^o \left(\sum_{i=1}^n \text{FComp}_{ki} + \sum_{j=1}^m \text{FComp}_{kj} \right)}$$

Where

Fcomp_{ki} is the number of daily frequencies (going and returning trains) proposed by rail operator i on the competing destination k

Fcomp_{kj} is the number of daily frequencies (going and returning flights) proposed by airline j on the competing destination k

2.4 Indicators of demand for inter-modality

2.4.1 Objectives

The objectives of these indicators are to measure the actual activity generated by inter-modal services (**inter-modal passengers transported**), as well as demand for these services. Measuring activity is indeed not sufficient to qualify demand for inter-modal services, as part of this demand may not have been satisfied: people may have organised their “inter-modal “ travel by themselves, or may have chosen another transport mode (airport access) or may have lacked adequate information on inter-

modal services. For example, a passenger wishing to go from Lyon to CDG in order to fly from there on an international flight may choose to fly there because the HST inter-modal service will not appear in the first screen of the reservation system. For this reason another interesting indicator would be the total **number of multimodal passengers**, which are passengers using rail and air but either inside or outside of the scope of an inter-modal agreement.

We also propose indicators relative to the potential demand of inter-modality at airport. It is important to note that this potential demand is not relative to a future demand for inter-modal services but more at the level of demand that is susceptible to use inter-modal services in the scope of the current rail network. In the scope of airport integration, when considering the existing HST network, we look at the **population who might be interested in using inter-modal transport**. **First, considering the existing service** (direct rail connection to the airport with an agreement), what is the potential demand for an inter-modal service? **Then, considering the network**, but supposing that the operators can offer more numerous direct services to the airport, what would be the potential demand? In the scope of airport access, we aim at determining **what are the passengers of the airport who could use an inter-modal transport to join the city?**

2.4.2 Proposed indicators

2.4.2.1 The number of inter-modal passengers transported

Ideally we would like to measure the **number of passengers using inter-modal services relative to the number of passengers who could use them** (some do, some do not): this is the average market share (in number of passengers) of inter-modal trips on all origin destination markets where an inter-modal service exists today

Ex : Suppose there is only one HST link from airport A to city B with an inter-modal agreement. In this case we would measure the number of inter-modal passengers using this HST link (for instance 10 000 passengers), divided by the total number of passengers leaving/arriving at city B (whether by air, rail or road) and connecting on a flight (where an inter-modal agreement exists) at airport A (for instance 50 000 passengers). The indicator of inter-modal passenger transported will be:

- *Indicator = $10\,000/50\,000=1/5=20\%$ for airport integration*

Suppose also that the airport A is connected to a dedicated rail link and that 100 000 passengers use this transport mode for accessing the airport in the scope of an inter-modal agreement while 300 000 passengers leave/arrive at airport A (by road or rail) for connecting on a flight where an inter-modal agreement exists. The indicator of inter-modal passenger transported will be:

- *Indicator = $100\,000/300\,000=1/3=33\%$ for airport access*

Unfortunately both measures necessary for computing this indicator can be very difficult to obtain. First, we would like to measure the total number of passengers transported and/or passenger-kilometres produced in the scope of inter-modal services. However, this data may not be published by inter-modal operators, and may not either be known by airport operators, except when a market survey is performed. This problem of data availability also exists for measuring the number of passengers flying to or from the airport on flights where inter-modal agreements exist.

That is why we propose an alternative indicator measuring the **number of passengers using inter-modal services relative to the total number of airport passengers that are not in transit**.

Ex : When considering the previous example applied to an airport with 10 millions passengers a year whose 30% are in transit, the indicators of inter-modal passengers transported will be:

- *Alternative Indicator = $10\,000/(10\,000\,000*(1-30\%))=0.14\%$ for airport integration*

- *Alternative Indicator = 100 000/(10000000*(1-30%))=1.4% for airport access*

Summary:

$$\text{Airport access indicator} = \frac{\sum_{i=1}^n \sum_{j=1}^m Pax_{ij}}{\sum_{j=1}^m PAX_j}$$

Where

Pax_{ij} is the number of passengers on flight j travelling in the scope of the inter-modal agreement for airport access i

PAX_j is the total number of passengers on flight j where inter-modal agreement for airport access exists

$$\text{Alternative Airport access indicator} = \frac{\sum_{i=1}^n \sum_{j=1}^m Pax_{ij}}{PAX_{NTrans}}$$

Where

PAX_{NTrans} is the number of passengers of the airport that are not in transit

$$\text{Airport integration indicator} = \frac{\sum_{k=1}^o \sum_{l=1}^p Pax_{kl}}{\sum_{l=1}^p PAX_l}$$

Where

Pax_{kl} is the number of passengers on flight l travelling in the scope of the inter-modal agreement for airport integration k

PAX_l is the total number of passengers on flight l where inter-modal agreement for airport integration exists

$$\text{Alternative Airport integration indicator} = \frac{\sum_{k=1}^o \sum_{l=1}^p Pax_{kl}}{PAX_{NTrans}}$$

Where

PAX_{NTrans} is the number of passengers of the airport that are not in transit

2.4.2.2 Number of multimodal passengers transported

Ideally we would like to measure the **percentage of passengers using successively rail and air** (whether they benefit from an inter-modal agreement or not) **relative to the number of passengers who could do it** (some do, some do not). We call these air +rail trips multimodal trips. This proposed indicator is therefore the average market share (in number of passengers) of multimodal trips on all origin destination markets where an inter-modal service exists today.

Ex : Suppose that 200 000 air passengers leave or arrive at the airport by rail access while 400 000 air passengers fly to or from the airport on flights where inter-modal agreements exist in the scope of airport access. The indicator of multimodal passenger transported will be:

- *Indicator = 200 000/400 000=1/2 for airport access*

Suppose also that 100 000 air passengers leave or arrive at the airport by HST access while 300 000 air passengers fly to or from the airport on flights where inter-modal agreements exist in the scope of airport integration. The indicator of multimodal passenger transported will be:

- *Indicator = 100 000/300 000=1/3 for airport integration*

In practice this indicator can be difficult to compute due to scarce availability of the needed data as well for airport access than for airport integration.

We therefore propose an alternative indicator measuring the **number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit.**

Ex : When considering the previous example applied to an airport with 10 millions passengers a year whose 30% are in transit, the indicators of multimodal passengers transported will be:

- *Alternative Indicator = 100 000/(10000000*(1-30%))=1.4% for airport integration*
- *Alternative Indicator =200 000/(10000000*(1-30%))=2.8% for airport access*

Summary:

$$\text{Airport access indicator} = \frac{\sum_{j=1}^m \text{Mod}_j}{\sum_{j=1}^m \text{PAX}_j}$$

Where

Mod_j is the number of passengers on flight j (where inter-modal agreement exist) that use an airport rail access before or after the flight (whether they benefit from an inter-modal agreement or not)
 PAX_j is the total number of passengers on flight j where inter-modal agreement for airport access exists

$$\text{Alternative Airport access indicator} = \frac{\sum_{j=1}^m \text{Mod}_j}{\text{PAX}_{N\text{Trans}}}$$

Where

$\text{PAX}_{N\text{Trans}}$ is the number of passengers of the airport that are not in transit

$$\text{Airport integration indicator} = \frac{\sum_{l=1}^p \text{Mod}_l}{\sum_{l=1}^p \text{PAX}_l}$$

Where

Mod_l is the number of passengers on flight l (where inter-modal agreement exist) that travel by regional or an high-speed train before or after the flight (whether they benefit from an inter-modal agreement or not)

PAX_l is the total number of passengers on flight l where inter-modal agreement for airport integration

exists

$$\text{Alternative Airport integration indicator} = \frac{\sum_{l=1}^p Mod_l}{PAX_{NTrans}}$$

Where

PAX_{NTrans} is the number of passengers of the airport that are not in transit

2.4.2.3 Potential demand for inter-modal service with current service levels

For airport integration, we consider the network and the inter-modal service offered by the operators as they are today. Looking at the rail destinations proposed in the scope of an inter-modal agreement, we try to estimate the potential demand for such services. In order to have an approximation of this demand, we estimate the **population of the destination cities, and weigh it by the percentage of the population of the country that travels yearly by air multiplied by the average number of trips each person makes**. We overlook the fact that people can travel “the other way round”, from a more or less distant origin, to one of the rail destination, since we have no opportunity to measure this demand. The aim of this indicator is only to give “orders of magnitude”, and not precise or accurate numbers.

Ex.: Suppose that the high-speed rail links linked to the airport serve 3 cities in a country where 30% of the population travels yearly by air with an average number of 2 trips per persons. If the population of the surrounding area of the cities A, B and C are 50 000, 70 000 and 40 000 respectively, the indicator of the potential demand for inter-modal service with current service levels will be:

- *Indicator = (50 000+70 000+40 000)*30%*2= 96 000 for airport integration*

If values of the percentage of the population of the country that travels yearly by air and/or the average number of trips each person makes are difficult to obtain we propose to compute an alternative indicator: the **population of the destination cities directly served by HST from the airport**.

Ex.: When considering the same example as above the alternative indicator of the potential demand for inter-modal service with current service levels will be:

- *Alternative indicator = 50 000+70 000+40 000=160 000 for airport integration*

Summary:

$$\text{Airport integration indicator} = \sum_{l=1}^p \sum_{k=1}^o Pop_{kl} \times Trav_l \times Trip_l$$

Where

Pop_{kl} is the population of the city k from the country l that is accessible by rail from the airport in a scope of an inter-modal agreement

$Trav_l$ is the percentage of the population of the country l that travels yearly by air

$Trip_l$ is the average number of trips each air traveller of country l makes per year

$$\text{Alternative Airport integration indicator} = \sum_{l=1}^p \sum_{k=1}^o Pop_{kl}$$

2.4.2.4 Potential demand for inter-modal service on existing network

For airport integration, we consider the current network, and look at the cities that could be served by train connection in a reasonable time. When referring to the state of the art on inter-modality that has been made in the study “The airport of the future: Central link of inter-modal transport?” [Ref 6], we consider this time to be a maximum time of 3 hours (corresponding to the time the train spend for joining the city railway station from the airport). We then look at the **population of this cities (areas), and weigh it by the percentage of the population of the country that travels yearly by air multiplied by the average number of trips each person makes**. As before, the goal is to give rough estimates of a maximum demand for inter-modal services, and not precise numbers.

Ex.: We consider the same example than in section 2.4.2.3. Suppose also that city A is connected by HST to a city Z with 30 000 inhabitants in its surrounding area . If we assume that the railway operator propose a service of 3 hours between the airport and the city Z (with a stop at city A), the indicator of potential demand for inter-modal service on existing network will be:

- *Indicator = (50 000+70 000+40 000+30 000)*30%*2= 114 000 for airport integration i.e. 19% higher than the indicator of the potential demand for inter-modal service with current service levels*

If values of the percentage of the population of the country that travels yearly by air and/or the average number of trips each person makes are difficult to obtain we propose to compute an alternative indicator: the **population of all the rail destination cities that could be directly linked to the airport in a journey time inferior to 3 hours**.

Ex.: When considering the same example as above the alternative indicator of potential demand for inter-modal service on existing network will be:

- *Alternative indicator = 50 000+70 000+40 000+30 000=190 000*

For airport access, we need to know the **number of passengers of the airport that are not connecting from/to another flight or a regional or high-speed train**. This will give us an upper bound of potential demand for inter-modal airport access, since a non-negligible proportion of these people can come from surrounding areas, and not from the city centre, and should therefore not be included as “potential clients” for inter-modal airport access.

Ex.: Suppose that among the 50 millions of passengers of the considered airport 20 millions are connecting from/to another flights and 10 millions are connecting to/from a travel by HST. The indicator of potential demand for inter-modal service on existing network will be:

- *Indicator = (50 000 000-20 000 000-10 000)=20 000 000 for airport access.*

Summary:

$$\text{Airport access indicator} = PAX_{NTrans} + PAX_{NTrain}$$

Where

PAX_{NTrans} is the number of airport passengers that are not in transit

PAX_{NTrain} is the number of airport passengers that are not connecting a regional or high-speed train

$$\text{Airport integration indicator} = \sum_{l=1}^p \left(\sum_{k=1}^o Pop_{kl} + \sum_{j=1}^m Pop_{jl} \right) \times Trav_l \times Trip_l$$

Where

Pop_{kl} is the population of the city k from the country l that is accessible by rail from the airport in a scope of an inter-modal agreement

Pop_{jl} is the population of the city j from the country l that could be served by rail from the airport in a scope of an inter-modal agreement in a maximum train journey time of 3 hours

$Trav_l$ is the percentage of the population of the country l that travels yearly by air

$Trip_l$ is the average number of trips each air traveller of country l makes per year

$$\text{Alternative Airport integration indicator} = \sum_{l=1}^p \left(\sum_{k=1}^o Pop_{kl} + \sum_{j=1}^m Pop_{jl} \right)$$

Categories of indicators	Objectives of indicators	Proposed indicators		Alternative indicators	
		Airport access	Airport integration	Airport access	Airport integration
Inter-modal infrastructure	Existence of rail infrastructure in the airport area	Number of rail infrastructure connected to the airport	Number of rail infrastructure connected to the airport	–	–
	Access time between the inter-modal infrastructure and the terminal	Access times between the airport railway station and the several terminals weighted by the proportion of passengers that can be handled in each terminal	Minimum connection time	Average of the different access times between the airport railway terminal and the airport terminals	–
	Rail capacity	Yearly capacity in number of passengers of the railway stations located in the airport area		–	–
	Interest of inter-modal infrastructure for airport users	Travel duration in number of days for which passengers would prefer to access the airport by rail than by using their private car	Number of cities that are served by train from the airport for a train journey time not exceeding 3 hours	–	–

Categories of indicators	Objectives of indicators	Proposed indicators	Alternative indicators	
Inter-modal operators	Number of inter-modal operators	Number of inter-modal air operators	–	–
		Number of inter-modal rail operators	–	–
		Number of non European airlines proposing inter-modal service	–	–
	Market share	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport	–	–

Categories of indicators	Objectives of indicators	Proposed indicators		Alternative indicators	
		Airport access	Airport integration	Airport access	Airport integration
Inter-modal service	Existence of inter-modal agreements	Number of agreements		-	-
	Specificities of inter-modal agreements	Number of characteristics of each agreement weighted by the yearly market share in ASKs of the airline operator summed up over all agreements		-	-
	Itermodal air supply	Number of inter-modal destinations by air relative to the total number of destinations		-	-
		Number of daily air frequencies summed up over all inter-modal destinations		-	-
	Itermodal rail supply	-	Number of inter-modal rail destinations	-	-
		Average daily frequencies of the airport rail access	Number of daily rail frequencies summed up over all inter-modal rail destinations	-	-
	Competition between air and rail	-	Number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air	-	-
		-	Number of daily frequencies by air on all competing routes, divided by the total number of daily frequencies (air+rail)	-	-

Categories of indicators	Objectives of indicators	Proposed indicators		Alternative indicators	
		Airport access	Airport integration	Airport access	Airport integration
Demand for inter-modality	Number of inter-modal passengers transported	Number of passengers using inter-modal services relative to the number of passengers flying to or from the airport on flights where inter-modal agreements exist		Number of passengers using inter-modal services relative to the total number of airport passengers that are not in transit	
	Number of multimodal passengers transported	Number of passengers using successively rail and air (whether they benefit from an inter-modal agreement or not) relative to the number of passengers flying to or from the airport on flights where inter-modal agreements exist		Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	
	Potential demand for inter-modal 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	–	Population of the destination cities directly served by train from the airport
	Potential demand for inter-modal service on existing network	Number of passengers of the airport that are not in transit	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 by air multiplied by the average number of trips each person makes	–	Population of all the rail destination cities that could be directly linked to the airport in a journey time inferior to 3 hours

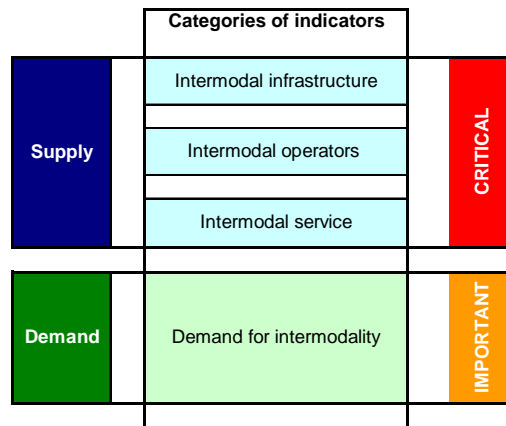
3 Indicators role and relative importance

The indicators presented aim at evaluating and comparing the level of inter-modality at airports. It is not possible to perform aggregation of the indicators since they don't refer always to the same units of measurement. Thus any analyses using the proposed indicators should focus on the individual value of the indicators, in addition to global qualitative analyses.

The existence of the required data for calculating the indicators will ensure a good level of information for the evaluation or comparison of the inter-modality level of a given airport. Nevertheless, the indicators role and importance within its category is different and doesn't affect the inter-modal status of a given airport in the same way. Some of the proposed indicators are dependent among them.

This chapter objective is to provide an overview on the role and relative importance of the proposed indicators, based on a qualitative analysis.

The indicators were grouped in four categories. Three of these categories are related to the supply side of the transport system, corresponding to infrastructures and services. The other is related to the demand side of the transport system.



Categories of indicators

The supply indicators play a critical role in an airport level of inter-modality. The existence of a suitable infrastructure (rail for airport integration and/or access) is the base for the development of any inter-modal services.

When it comes to demand, usually the existence of an infrastructure and related services should be the response to an existing or potential demand. Subsequently, existing and potential demand play an important role in evaluating an infrastructure level of inter-modality and market development potential, but the existence of inter-modal demand can only occur if there is a supply of inter-modal services. As for the potential demand, it can be used as a driver for the development of inter-modal services or investment in new infrastructures.

Following this, when analysing indicators for a given airport the relative importance of supply and demand categories should be considered in order to evaluate the basic limitations or potential for inter-modal development.

In essence, it should be considered that:

1. Supply side indicators play a critical role. Within this group of indicators inter-modal infrastructure is the key element since it is the base for the development of any services.
2. Demand (existing or potential) is an important element since the services must have passengers in order to be economically feasible.

3.1 Role and importance of indicators in supply and demand categories

When changing to a more detailed analysis scale, the role and importance of different individual indicators in each of the categories must be considered.

3.1.1 Supply categories

The proposed supply indicators are divided in 3 categories – Inter-modal infrastructure, inter-modal operators and inter-modal services.

The next chart presents an indication of the relative importance level of the different categories indicators.

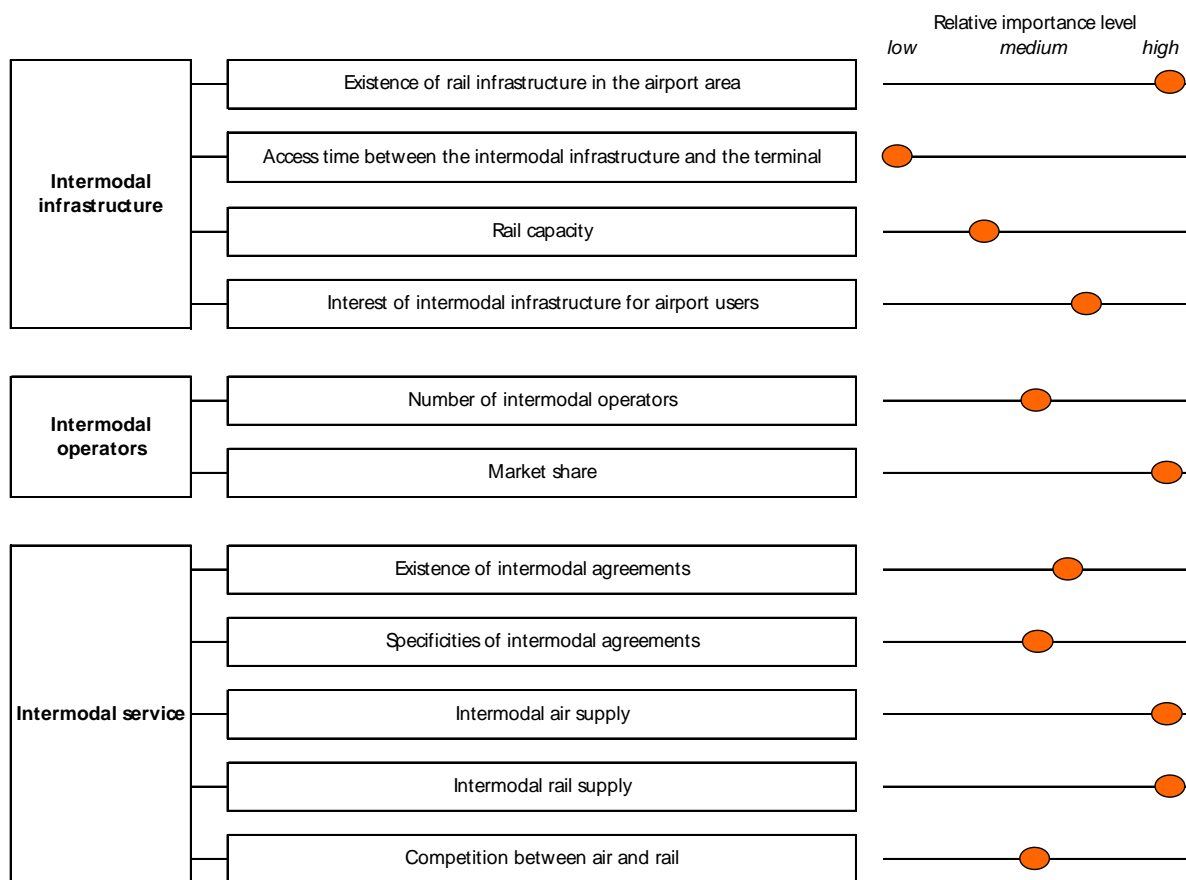


Figure 1: Importance of indicators in each supply categories

At a macro-analysis level, the following indicators are highlighted:

- The existence of rail infrastructure in the airport area is the basis for developing inter-modality at an airport. Consequently, it has the highest relative importance level with regards to the other inter-modal infrastructure indicators;
- Also, the market share indicator is of primary importance since it captures the fact that the dominant airlines have a strong influence of the supply of inter-modality at an airport. As an example, if the dominant airline (with e.g. 40% of the airport’s market) has not inter-modal agreements with rail, the airport does not provide significant levels of inter-modality even if many other airlines are “inter-modal”;

- With regards to inter-modal service, two indicators should be highlighted. For the case of airport integration these indicators are the number of inter-modal destinations provided by air and the number of destinations provided by rail. For airport access the two more relevant indicators are the number of inter-modal destinations provided by air and the average daily frequency of the airport rail access. These indicators have been highlighted as they determine the levels of all other indicators of inter-modal service. As an example, if the number of inter-modal air or rail destinations is “0”, the number of agreements and all other associated indicators is also “0”.

3.1.2 Demand category

As explained the demand indicators are globally less important than the supply categories.

However, there is still one very important indicator to be highlighted, the number of multimodal passengers transported. Indeed, this indicator gives the global indication of demand from passengers towards inter-modality since it gives both the levels of actual inter-modality (in the scope of agreements) and the levels of potential inter-modality (considering that passengers who are already multimodal passengers should easily become inter-modal passengers if agreements are signed).

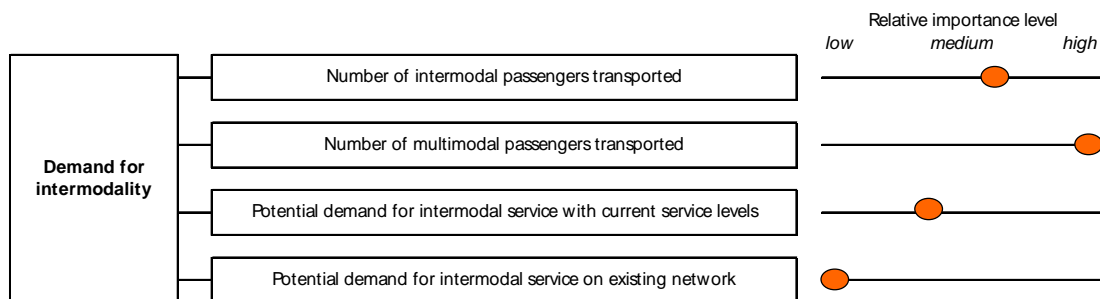


Figure 2: Importance of indicators in the demand side category

3.2 Synthesis of indicators

Following the analysis performed in § 3.1, there are a certain number of “macro-level” indicators aimed at providing the broad picture of inter-modality at an airport.

At the supply side, “macro-level indicators” are the following:

- Inter-modal infrastructure:
 - the number of rail infrastructure connected to the airport;
- Inter-modal operators:
 - yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport;
- Inter-modal service:
 - Number of inter-modal destinations by air relative to the total number of destinations;
 - Average daily frequencies of the airport rail access;
 - Number of inter-modal rail destinations (airport integration).

At the demand side, the “macro-level indicator” is the following:

- Demand for inter-modality:
 - Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit.

The above “macro-level” indicators may be used to conduct a first step analysis of inter-modality at the airports. They should provide the global picture of inter-modality, and should help to the evaluation of the levels of the airports’ development with regards to inter-modality.

In a second step, and for the airports which are already well developed in terms of inter-modality, the other indicators (those defined in previous § 2), by providing a more detailed analysis on the features of inter-modality, might be useful for benchmarking purposes.

4 Application airports

4.1 Paris Charles de Gaulle airport

4.1.1 General presentation

Charles de Gaulle (CDG) airport is located at 23 kilometres north east of Paris near the village of Roissy-en-France. With its 51.3 millions of passengers in 2004, CDG airport is the second European airport before Frankfurt and behind London Heathrow. The 487 564 flights arriving or departing from CDG airport in 2004 were operated by 130 airlines offering 269 national and international destinations. 35% of these 51.3 millions of passengers are transit passengers.



Figure 3: Charles de Gaulle airport
(Source Aéroport de Paris)

The airport can be reached by rail thanks to the RER B, a suburban rail link in 30 minutes from Gare du Nord station. Travel times from other stations in Paris are available in Annex A. Trains are operated by the Société Nationale de Chemins de Fer (SNCF) with a frequency of 15 minutes between 5h30 AM and 11h30 PM. The ticket fare is 7.85€ for one trip.

Passengers that use the RER B to connect the airport account for 19% of the total number of passengers travelling to/from Paris CDG airport (2003 figure).

Two different bus operators provide connections to the airport from Paris city centre:

- The Régie Autonome des Transports Parisiens (RATP) operating:
 - RoissyBus connecting the airport from “Opera Garnier” in 45 to 60 minutes, with a frequency of 15 minutes between 5h45 AM and 11h00 PM;
 - Bus lines 350 connecting the airport from a bus stop at Gare de l’Est;
 - Bus lines 351 connecting the airport from a bus stop at Nation.

- Air France operating Air France buses between CDG airport and:
 - Paris Orly airport every 30 minutes;
 - Gare Montparnasse with deposits of passengers at Porte Maillot and Etoile/Place Charles de Gaulle. The bus frequency is 15-20 minutes with a travel time between 25 minutes and 1 hour depending on road congestion levels.



Figure 4: TGV Station in Roissy Charles de Gaulle airport

In 2003, only 9% of passengers' traffic to CDG was by buses (either Air France or RATP buses)

The airport is fully integrated in the high-speed rail network thanks to a high-speed train station. This allows the airport to be directly linked by rail to several cities:

- Aix en Provence with 7 trains to and from the airport by day;
- Angers with 8 trains to and from the airport by day;
- Avignon with 11 trains to and from the airport by day;
- Bordeaux with 11 trains to and from the airport by day;
- Le Mans with 9 trains to and from the airport by day;
- Lille with 43 trains to and from the airport by day;
- Lyon with 22 trains to and from the airport by day;
- Marseille with 13 trains to and from the airport by day;
- Montpellier with 9 trains to and from the airport by day;
- Nantes with 8 trains to and from the airport by day;
- Nimes with 9 trains to and from the airport by day;
- Poitiers with 11 trains to and from the airport by day;
- Rennes with 8 trains to and from the airport by day;
- Saint-Pierre des Corps with 11 trains to and from the airport by day;
- Valence with 14 trains to and from the airport by day;
- Brussels (in Belgium) with 10 trains to and from the airport by day.

While the SNCF offers connections to all the French cities, Thalys International operates on link to and from Brussels.

Among the total yearly passengers of Paris CDG airport, 3.3% use the high-speed train for connecting to or from a flight (source Groupe de travail GUYARD [Ref 3]).

General information	2004 Values
Total number of yearly passengers in 2004	51 300 000
Total number of destinations proposed by the airport	269
Total number of airlines operating at the airport	130
Total number of rail transport operators operating at the airport	3
Total yearly PKTs supplied by all airlines to and from the airport	Not Available
Total yearly ASKs supplied by airlines to and from the airport	2,5E+11
Total capacity in number of passengers of the airport	164 474 475

Table 5: General information on the CDG airport

4.1.2 Inter-modal agreements

If no inter-modal agreements exist for airport access, there are two different inter-modal agreements TGV Air and agreement with Thalys International.

4.1.2.1 TGV Air

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

This agreement holds that the transporting of international passengers between Lille and CDG is made by TGV while Air France cancels its flights between Lille and CDG. This organized bimodality does not concern the luggage check-in but allows passengers to buy tickets grouping international flights preceding or following TGV journeys. The TGV journey has a flight number and appears in the air reservation system. The TGV AIR product is therefore distributed and commercialised by Air France and by all travel agencies in the world.

SNCF also has TGV AIR agreements with other airlines such as Air Austral, American Airlines, Continental Airlines, Delta Air Lines, KLM, Emirates, Cathay Pacific, Qatar Airways, Air Tahiti Nui, Lufthansa and United Airlines.

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

- Aix-en-Provence TGV ;
- Angers Saint-Laud ;
- Avignon TGV ;
- Bordeaux Saint-Jean ;
- Le Mans ;
- Lille-Europe ;

- Lyon Part-Dieu ;
- Marseille Saint-Charles ;
- Montpellier, St Roch ;
- Nantes ;
- Nîmes;
- Poitiers ;
- Rennes ;
- Saint-Pierre-des-Corps (Tours) ;
- Valence TGV.

Among these 15 destinations only 10 have a train journey time not exceeding 3 hours:

- Angers Saint-Laud ;
- Avignon TGV ;
- Le Mans ;
- Lille-Europe ;
- Lyon Part-Dieu ;
- Nantes ;
- Poitiers ;
- Rennes ;
- Saint-Pierre-des-Corps (Tours) ;
- Valence TGV.

In addition, only Air Austral, Air Tahiti Nui and Qatar Airways propose the TGV Air product on all these rail destinations. The other airlines propose this agreement on a part of the possible TGV Air products.

	Air Austral	Air France	Air Tahiti Nui	American Airlines	Cathay Pacific	Continental airlines	Delta Airlines	Emirates	KLM	Lufthansa	Qatar Airways	United Airlines
Aix en Provence	X		X				?				X	
Angers Saint-Laud	X	X	X	X		X	?		X	X	X	X
Avignon TGV	X		X	X		X	?	X			X	X
Bordeaux Saint-Jean	X		X	X	X	X	?	X		X	X	X
Le Mans	X	X	X	X		X	?		X	X	X	X
Lille-Europe	X	X	X	X	X	X	?	X	X	X	X	
Lyon Part-	X	X	X	X	X	X	?	X	X	X	X	X

Dieu												
Marseille Saint-Charles	X		X	X	X	X	?				X	X
Montpellier, St Roch	X		X	X	X	X	?				X	X
Nantes	X	X	X	X	X	X	?	X	X	X	X	X
Nîmes	X		X			X	?	X			X	
Poitiers	X	X	X	X		X	?		X	X	X	X
Rennes	X		X	X		X	?	X		X	X	X
Saint-Pierre-des-Corps (Tours)	X	X	X	X	X	X	?		X	X	X	X
Valence TGV	X		X			X	?				X	X

Table 6: Rail destinations proposed by airlines in the scope of TGV Air

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

The second drawback of the TGV AIR principle concerns the check-in that is only proposed by Air France. In each TGV station Air France passengers get their TGV ticket as well as their boarding pass for the flight indicating their seat number in the aircraft. Nevertheless this check-in does not concern the luggage check-in that has to be made at the airport. In general the absence of luggage check-in means that passengers have to get their luggage themselves on the train.

The correspondence time (minimum connecting time defined by the airlines) between the TGV arrival and the flight departure depends on the terminal of flight departure and can reach 90 min.

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

At the present time, the display rules of reservation systems penalize the TGV AIR product since the display is done according to the journey time of the total trip. The offer TGV+aircraft does not appear on the first screen.

As Air France, Air Austral and United Airlines allow to buy the tickets on Internet.

Inter-modal agreement	Airlines	Global reservation	Check-in with luggage only	Market share in ASKs at the airport
TGV Air	Air France	X	X	50%
	KLM	X		0,1%

	Continental Airlines	X		1%
	American Airlines	X		3%
	United Airlines	X		3%
	Air Tahiti Nui	X		1%
	Qatar Airways	X		0,3%
	Air Austral	X		1%
	Emirates	X		0,1%

Table 7: Features of TGV Air inter-modal agreements

4.1.2.2 Thalys International inter-modal agreement

This agreement signed in 2001, holds that Air France stops operating flights between CDG and Brussels and that all Air France passengers are transported from Brussels to CDG via Thalys International trains with a train journey time of approx. 1 ½ hour.

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

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

Thalys International has other bimodal agreements with American Airlines and Air Austral between CDG airport and Brussels Midi station.

Inter-modal agreement	Airlines	Global reservation	Check-in with hand luggage only	Market share in ASKs at the airport
Thalys International agreement	Air France	X	X	50%
	American Airlines	X		3%
	Air Austral	X		1%

Table 8: Features of Thalys Inter-modal agreements at CDG airport

4.1.3 Inter-modal traffic

All air destinations proposed in the scope of TGV Air and Thalys international agreements are international. This means that national destinations of Air France (i.e. 11% of the total destinations of Air France at the airport) do not belong to the offered destinations in the scope of the agreement. 156 different air destinations arriving or departing from CDG airport are therefore concerned by this agreement and can be considered as “inter-modal air destinations”. The airlines having concluded these two inter-modal agreements have supplied in 2004 1.49 E+11 available seat kilometres to and

from the airport.

Among the 18 Air France's destinations that are not inter-modal, six are in competition with the high-speed train:

- Bordeaux ;
- Lyon;
- Marseille ;
- Montpellier ;
- Nantes;
- Rennes.

It is moreover interesting to note that among these 6 TGV destinations in competition with air only Nantes and Lyon are TGV destinations belonging to the Air France TGV Air agreement with SNCF, what tends to mean that Air France wants to favour its national air destinations. As national flights are all performed by Air France we will consider that only two destinations are offered by rail in the scope of an inter-modal agreement where there is also a service by air.

In general, we observe that the number of daily flights to or from these destinations does not exceed the number of daily trains.

Competing Destination	Number of daily flights to or from the destination	Number of daily trains to or from the destination
Lyon	12	22
Nantes	8	8

Table 9: Number of daily flights and trains to or from the inter-modal destinations in competition between air and rail

Both destinations can be reached by train in a train journey time not exceeding 3 hours meaning that both can be considered as competing destinations. If the air and rail daily frequencies to and from Nantes are the same, the number of daily trains to and from Lyon is quite the double of the daily flights.

4.1.4 Collected data

Table 10 and Table 11: Collected data for CDG airport, summarise the information collected that will be used for building the indicators, differentiated according to the case of airport access and airport integration in the rail network.

Although a rail airport access exists at CDG airport, no inter-modal agreements have been concluded between its operator (RATP) and airlines. As a consequence data relative to inter-modality for airport access are equal to zero.

Data	Airport access	Airport integration
Number of rail transport infrastructures connected to the airport (dedicated rail link, non dedicated rail links, etc.)	1	1
Total capacity in number of passengers of the railway stations	Not Available	Not Available
Minimum connection time between rail and air transport modes (in minutes)	-	71
Total number of inter-modal agreements between air and ground operators	0	11
Number of inter-modal air destinations	0	156
Number of inter-modal rail destinations	0	16
Number of yearly inter-modal passengers in a context of an inter-modal agreements	0	Not Available
Number of multimodal passengers using successively rail and air (or air and rail)	Not Available	1692900
Number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air	-	2
Number of inter-modal air operators	0	8
Number of inter-modal rail operators	0	2
Number of non-European air carriers proposing inter-modal services	0	6
Total yearly PKT of inter-modal flights	0	Not Available
Total yearly ASKs of inter-modal flights	0	1,49E+11
Access time (in minutes) between terminal 1 and the airport railway station	10	-
Access time (in minutes) between terminal 2 and the airport railway station	3	-
Access time (in minutes) between terminal 3 and the airport railway station	8	-
Access time to the airport by car (in minutes) from the city centre	[45;90]	-
Price of rail access journey (in euros)	7,85	-

Table 10: Collected data for CDG airport

Data	Airport access	Airport integration
Time of rail access journey (in minutes)	59	
Average value of time (in euro per minute) of passengers accessing the airport by rail	0,32	-
Average value of time (in euro per minute) of passengers accessing the airport by private car	0,18	-
Daily price of airport parking	22,5	-
Average price of airport access by private car (in euros)	4,60	-
Number of cities that are served by train from the airport for a train journey time not exceeding 3 hours	-	11
Number of airport passengers in transit (to and from a flight)	-	17955000
Number of airport passengers accessing the airport by rail	9747000	-
Number of airport passengers accessing the airport by other transport modes than rail	Not Available	-
Population of cities directly served by train from the airport.	-	11987275
Proportion of passengers using terminal 1	18%	-
Proportion of passengers using terminal 2	77%	-
Proportion of passengers using terminal 3	5%	-
Percentage of the population of the country that travels yearly by air	-	26%
Average number of trips each air passenger makes by year	-	2,5

Table 11: Collected data for CDG airport

The minimum connecting time between HST arrival and flights departure is 60 minutes for Air France (in the scope of TGV Air as well as in the Thalys agreement) and 120 minutes for the other inter-modal airlines. For computing the average minimum connecting time at CDG airport we have weighted these times by the share of ASKs each airlines supplies in the scope of these inter-modal agreements. Hence as Air France supplies 82% of the total yearly ASKs of inter-modal flights the average minimum connecting time is $60 \cdot 82\% + 120 \cdot 18\% = 71$ minutes.

The total rail access time has been computed by weighing the rail journey time to each terminal according the terminal capacities by adding to this value the average time to get the railway station from home (6 minutes). The 6 minutes for getting the station from home have been estimated by weighting the station access time for each Paris “arrondissement” (source RATP) with the population of each “arrondissement”. More details on this estimation are presented in Annex A.

The time for performing the 23 kilometres from the city centre to the airport ranges from 45 minutes (without congestion) to 90 minutes (in case of high congestion). The congestion risk factor is then 1,5. When assuming that the average cost by kilometre of using a car for accessing the airport is 0.20 euro,

the average price of airport access by private car is 4.60 euros.

Values of average value of time of passengers accessing airport by car and by rail in France come from the Commissariat General au plan ([Ref 1]).

4.2 London Heathrow airport

4.2.1 General presentation

London Heathrow airport is 24 kilometres west of the centre of London at the limit of the London urban area delimited by the London's M25 beltway. The airport is ranked No.1 on the European list of airports in terms of passenger number – 67.3 millions of passengers in 2004 – and No.3 in terms of air transport movements (503 099 movements in 2004). 35% of these 67.3 millions of passengers are transit passengers (source: Heathrow Association for the Control of Aircraft Noise [Ref 4]).

Heathrow services 217 destinations (mostly international), operated by 92 airlines.



Figure 5: Heathrow airport
(Source the Liaison Group of UK Airport Consultative Committees)

Buses and rail links provide connections with Central London and suburban towns around the airport. Connections to other cities in the UK are ensured by long-distance buses departing/arriving directly from/to the airport:

- Most of bus services operate from the central bus station, which is located in the heart of the airport next to the underground station for the terminals 1, 2 and 3. Buses services link the airport with a lot of towns around the airport and with the heart of London. On top of this local bus services, the central bus station is also dedicated to the transport of passengers between London Heathrow airport and many other UK cities (express bus network serving all the UK).

The express bus service for Central London is the “Airbus” link that connects all terminals with many London hotels and some main line rail stations. It departs every 20 – 30 minutes and the transport time between the airport and the centre of London is about 1 hour.

In 2002, the proportion of passengers travelling to Heathrow airport by bus was about 13%;

- Heathrow has two stations on London Underground's Piccadilly Line, one station for Terminals 1, 2 & 3 and one for Terminal 4. The average journey time to central London is about 50 – 60 minutes. Trains run every 5 minutes at peak times and every 9 minutes at off-peak times and weekends. The ticket fare for one journey is 5.70 euros.

In 2002, the proportion of passengers travelling to Heathrow airport by the underground was about 13%;

- The Heathrow Express train offers full check-in services for passengers of various airlines at Paddington Station in the heart of London. Trains connect the terminals with the Paddington Station in 15 minutes (Terminals 1, 2 and 3) or 20 minutes (Terminal 4). They run every 15 minutes from 05:00 to 23:50, 365 days a year. The ticket fare for one journey is 35 euros in first class and 21 euros in second class.

In 2002, the proportion of passengers travelling to Heathrow airport by Heathrow Express trains was about 8%.

General information	2004 Values
Total number of yearly passengers in 2004	67 300 000
Total number of destinations proposed by the airport	184
Total number of airlines operating at the airport	92
Total number of rail transport operators operating at the airport	2
Total yearly PKTs supplied by all airlines to and from the airport	Not Available
Total yearly ASKs supplied by airlines to and from the airport	4,2E+11
Total capacity in number of passengers of the airport	209 802 000

Table 12: General information on the London Heathrow airport

4.2.2 Inter-modal agreements

As opposed to other major airports in Europe, London Heathrow airport is not yet connected to the national or international rail network.

By contrast, inter-modality with regards to the airport access has significantly improved since the introduction of the dedicated Heathrow Express rail service to the airport.



Figure 6: Heathrow Express

Agreements between the Heathrow Express Operating Company and some major airlines have been signed in order to provide a luggage check-in and handling service: passengers are able to collect their boarding cards at Paddington station and ride the Heathrow Express train free of luggage

transportation. Their luggage is handling directly from Paddington up to their final destination. These full check-in facilities are available for the following airlines: British Airways, Air Canada, Lufthansa, British Midlands, Finnair, Qantas, SAS, Singapore Airlines, SriLankan Airlines, Thai Airways, Varig Brasil, LOT and Australian Airlines.

While providing full check-in services at the Paddington Station, Heathrow Express does not provide however an integrated ticketing service. Passengers travelling to the airport via the Heathrow Express still have to buy two different tickets for their trip: one corresponds to the usual airline ticket and the other one is the Heathrow Express coupon bought at the station.

Inter-modal agreement	Airlines	Global reservation	Check-in with luggage
Heathrow Express agreement	British Airways	X	X
	Air Canada	X	X
	Lufthansa	X	X
	British Midlands	X	X
	Finnair	X	X
	Qantas	X	X
	SAS	X	X
	Singapore Airlines	X	X
	SreLankan Airlines	X	X
	Thai Airways	X	X
	Varig Brasil	X	X
	LOT	X	X
	Australian Airlines	X	X

Table 13: Features of Heathrow Express inter-modal agreements

4.2.3 Inter-modal traffic

All air destinations are proposed in the scope of Heathrow Express inter-modal agreements. This means that the 13 inter-modal airlines offer international but also national destinations in the scope of these agreements. 154 different air destinations arriving or departing from London Heathrow airport are therefore concerned by these agreements and can be considered as “inter-modal air destinations”. At present, the Heathrow Express dedicated rail link is used by about 15 000 passengers every day and the objective is to reach 6 million passengers per year in the near future.

4.2.4 Collected data

The table below provides a summary of the information collected that will be used for building the indicators, differentiated according to the case of airport access and airport integration in the rail network.

As the airport is not directly integrated into the national and international rail network, data relative to inter-modality for airport integration are equal to zero.

Data	Airport access	Airport integration
Number of rail transport infrastructures connected to the airport (dedicated rail link, non dedicated rail links, etc.)	2	0
Total capacity in number of passengers of the railway stations	Not Available	Not Available
Minimum connection time between rail and air transport modes (in minutes)	-	0
Total number of inter-modal agreements between air and ground operators	13	0
Number of inter-modal air destinations	154	0
Number of inter-modal rail destinations	1	0
Number of yearly inter-modal passengers in a context of an inter-modal agreements	Not Available	0
Number of multimodal passengers using successively rail and air (or air and rail)	14 133 000	0
Number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air	-	0
Number of inter-modal air operators	13	0
Number of inter-modal rail operators	1	0
Number of non-European air carriers proposing inter-modal services	7	0
Total yearly PKT of inter-modal flights	Not Available	0
Total yearly ASKs of inter-modal flights	2,3E+11	0
Access time to the airport by car (in minutes) from the city centre	[45,70]	-
Price of rail access journey (in euros)	6	-
Time of rail access journey (in minutes)	55	-
Average value of time (for one minute) of passengers accessing the airport by rail	0,22	-
Average value of time (for one minute) of passengers accessing the airport by private car	0,14	-
Daily price of airport parking	22,5	-
Average price of airport access by private car (in euros)	5	-

Table 14: Collected data for Heathrow airport

Data	Airport access	Airport integration
Access time between terminal 1 and the airport railway station	9	-
Access time between terminal 2 and the airport railway station	6	-
Access time between terminal 3 and the airport railway station	12	-
Access time between terminal 4 and the airport railway station	3	-
Price of rail access journey (in euros)	6	-
Time of rail access journey (in minutes)	75	-
Number of airport passengers in transit (to and from a flight)	23 555 000	-
Proportion of passengers using terminal 1	39%	-
Proportion of passengers using terminal 2	14%	-
Proportion of passengers using terminal 3	25%	-
Proportion of passengers using terminal 4	22%	-

Table 15: Collected data for Heathrow airport

In order to compute an average price for the rail access we have weighted the Heathrow Express prices and the underground price with their corresponding share of rail passengers using each of them. The price for one journey with underground is 5.70€ while the price with Heathrow Express is 35€ in first class and 21€ in second class. Hence as only 38% percent of passengers accessing the airport by rail access use Heathrow Express, the average price is $(35+21)/2*38\%+5.7*62\%=14$ euros.

The total rail access time has been computed by weighing the rail journey time to each terminal according to the terminal capacities, by adding to this value the average time to get the railway station from home, and by adding the access times to the terminals from the Heathrow railway stations. In order to compute the average access time by rail, we have weighted also the Heathrow Express access times and the underground access times.

The time for getting the airport from the city centre by private car ranges from 45 to 70 minutes. The congestion risk factor is then 1,2. When assuming that the average price per kilometre of accessing the airport by car is 0.2 euro, the average price of performing the 23 kilometres by car is 5 euros.

Values of average value of time of passengers accessing airport by car and by rail in United-Kingdom come from the Commissariat General au plan ([Ref 1]).

4.3 Frankfurt airport

4.3.1 General presentation

Frankfurt airport is located 12 kilometres southwest of the city centre. The airport is ranked No. 3 on the European list of airports in terms of passenger number – 51.1 millions of passengers in 2004 – and also No.3 in terms of air transport movements (462 860 movements in 2004).

There are 123 airlines offering a passenger service to a list of 336 national and international

destinations (148 of them outside Europe).



**Figure 7: Frankfurt airport
(Source Fraport)**

Public transport services (buses and rail services) link the airport with the city centre, suburban towns and other cities of Germany and of some European countries.

- Buses operating at the airport include:
 - Lines No. 61 and 62 that link the airport with the city centre. There are buses every 20 minutes;
 - The Lufthansa Courtesy Airport Bus which connects the airport with Mannheim (travel time – one hour) and Heidelberg (travel time – one hour 30 minutes);
 - Long-distance buses that serve the Czech Republic (T271 to Ostrava with a travelling time of 4 hours) and France (Strasbourg with a travelling time of 3 hours).

In 2002, the proportion of passengers using buses to connect the airport was 6 %.

- The rail connection is particularly developed at the airport. Frankfurt airport has high speed, regional and suburban services:
 - Local (suburban) / Regional trains (“S-bahn” trains operated by the German operator “Deutsche Bahn”) link the centre of Frankfurt in less than 15 minutes (e.g. travelling time to the Central station is 12 minutes). Trains depart from the local and regional railway station situated underneath Terminal 1’s arrival hall. In total there are 213 local / regional trains per day. The price of one journey is 3.25€



Figure 8 : S-Bahn train

In 2002, the proportion of passengers using local and suburban trains to connect the airport was 12 %

- High-speed trains connect the airport with other cities (e.g. Düsseldorf, Stuttgart, Cologne, Munich) and also other European countries, with for example connections to Amsterdam and Brussels. The German Operator, “Deutsche Bahn” operates 163 high-speed trains per day from a dedicated railway station at the airport (the “AIRail Terminal” situated right next to Terminal 1 and next to the local / regional railway station). The proportion of passengers arriving on long-distance trains increased from 7 to 18 percent between 1998 and 2004 – more than 4.2 million people in 2004.

High-speed connections have also enhanced the airport’s catchment’s area. As an example, Fraport reported that the number of passengers arriving from a distance of more than 100 km increased from 31 to 41 percent since 1998.



Figure 9 : ICE train

General information	2004 Values
Total number of yearly passengers in 2004	51 100 000
Total number of destinations proposed by the airport	336
Total number of airlines operating at the airport	123
Total number of rail transport operators operating at the airport	2
Total yearly PKTs supplied by all airlines to and from the airport	Not Available
Total yearly ASKs supplied by airlines to and from the airport	2,7E+11
Total capacity in number of passengers of the airport	128 115 000

Table 16: General information on Frankfurt airport

4.3.2 Inter-modal agreements

Although no inter-modal agreements exist for airport access, there are at the current time three different inter-modal agreements between air and rail at Frankfurt airport: “AiRail Services”, “Rail&Fly” and “Good for Train”.

Another agreement named “Intercity services” allowing a common booking for the whole travel by air and train, has also been concluded between the Deutsche Bahn and Lufthansa airline but does not exist anymore. We will therefore not consider it as a current existing inter-modal agreement.

4.3.2.1 AiRail services

AiRail Service is a joint venture of Deutsche Lufthansa, Deutsche Bahn and Fraport (the manager of Frankfurt airport) existing from May 2003. The service allows passengers to check in their flight baggage and receive their boarding passes for their flight from Frankfurt already at the Stuttgart or Cologne’s central train stations. All flight baggage will be checked through to passengers’ final destination. Baggage may also be checked in the night before your flight. In the case of a successive air/rail trip, passengers can also check-in for the whole trip at the departing airport and do not have to reclaim their baggage before having reached Cologne or Stuttgart railway station.

AiRail passengers have reserved seats on the ICE train. Passengers flying first or business class travel first class and passengers flying economy class travel second class on the train. The travel time between Stuttgart and Frankfurt airport is 73 minutes with 7 daily ICE-train connections while the travel time from Cologne and Frankfurt airport is 57 minutes with 16 daily connections. All Lufthansa flights are proposed in the scope of this AiRail service.

4.3.2.2 Rail&Fly

Rail&Fly is a combined service between the Deutsche Bahn and 94 airlines listed below:

Aeroflot Russian Airlines	Air Astana	Air Canada
Aerolineas Argentinas	Air Baltic	Air China

Air India	Aviation Co	Maersk Air
Air Lithuania	Donbassaero	Mahan air
Air Malta	Egyptair	Malaysia Airlines
Air Mauritius	El Al Israel Airlines	Martin Air
Air Namibia	Emirates	MIAT Mongolian airlines
Air Partner	ENKOR	Middle East Airlines
Air Seychelles	Eritrean Airlines	Montenegro Airlines
Air Transat A.T.Inc.	Estonian Air	Pakistan International Airlines
Albanian Airlines	Ethiopian Airlines	Pro Sky Airbroker
Alitalia	Etihad Airways	Pulkovo Aviation Enterprise
American Airlines	Finnair	Qantas Airways
ANA	Georgian airlines	Qatar Airways
Asiana Airlines	Gulf Air	Royal Air Maroc
Belavia	Hemus air	Royal Brunei Airlines
Biman Bangladesh Airlines	Iberia	Royal Jordanian
Bulgaria Air	Icelandair	SATA International
Cabo Verde Airlines	Iran Air	Siberia Airlines
Carpatair	Japan Airlines	Singapore Airlines
Cathay Pacific Airways	JAT - Jugoslovenski Aerotransport	SN Brussels
China Airlines	Kavminvodyavia	South African Airways
China Eastern Airlines	Korean Air	SriLankan Airlines
Cirrus Airlines	Kuban airlines	Syrian Arab Airlines
Continental Airlines	Kuwait Airways	TAP Air Portugal
Croatia Airlines	L.T.U. International Airways	Tarom
Cyprus Airways	LAN-Chile	Thai Airways International
Czech Airlines	Lithuanian Airlines	
Delta Air Lines	Lufthansa German Airlines	
Dnieproavia Joint Stock		

This service allows travelling by rail (on all trains (including ICE) except Thalys, DB Autozug) throughout Germany to Frankfurt Airport, when using the air ticket. The global check-in for the whole trip is not possible in the case of Rail&Fly services.

4.3.2.3 Good for Train

This service is the resulting of an agreement between the Deutsche Bahn and Lufthansa for transferring passengers on national destinations to train when flights are cancelled. Hence this service can be offered to passengers in transit in Frankfurt airport and flying from Frankfurt airport to a national destination already served by the train from the airport. As a consequence it is not always an

inter-modal service and will not be considered in this study.

Inter-modal agreement	Airlines	Global reservation	Check-in with hand luggage only	Check-in with luggage	Market share in ASKs at the airport
AiRail services	Lufthansa	X	X	X	48%
Rail&Fly	All 94 airlines	X			88%

Table 17: Features of AiRail services and Rail&Fly inter-modal agreements

4.3.3 Inter-modal traffic

All air destinations are proposed in the scope of AiRail Services and Rail&Fly. This means that Lufthansa offers its international but also national destinations in the scope of the agreements. 256 different air destinations arriving or departing from Frankfurt airport are therefore concerned by these agreements and can be considered as “inter-modal air destinations”.

Among the national inter-modal destinations, 5 are in competition with the high-speed train (with a train journey time less than 3 hours):

- Cologne
- Düsseldorf
- Hanover
- Nuremberg
- Stuttgart

Among these competing destinations only two are proposed by direct train (more precisely direct high-speed train). The others require taking at least two different trains. Rail&Fly inter-modal agreements do not only concern high-speed train since regional trains or intercity trains can also be used in the scope of this agreement. As a consequence there is a large range of possibilities from travelling between to and from the airport and the number of daily trains exceeds largely the number of daily flights.

Competitive destinations	Number of daily flights to or from the destination	Number of daily trains to or from the destination
Cologne	8	102
Düsseldorf	17	98
Hanover	12	48
Nuremberg	12	50
Stuttgart	12	64

Table 18: Number of daily flights and trains to or from the destinations in competition between air and rail

The 94 airlines having concluded these two inter-modal agreements have supplied in 2004 2.37 E+11 available seat kilometres to and from the airport.

4.3.4 Collected data

Table 19 and Table 20: Collected data for Frankfurt airport, summarise information collected that will be used for building the indicators, differentiated according to the case of airport access and airport integration in the rail network.

Although a rail airport access exists at Frankfurt airport, no inter-modal agreements have been concluded between its operator and airlines. As a consequence data relative to inter-modality for airport access are equal to zero.

Data	Airport access	Airport integration
Number of rail transport infrastructures connected to the airport (dedicated rail link, non dedicated rail links, etc.)	1	2
Total capacity in number of passengers of the railway stations	Not Available	Not Available
Minimum connection time between rail and air transport modes	-	45
Total number of inter-modal agreements between air and ground operators	0	95
Number of inter-modal air destinations	0	256
Number of inter-modal rail destinations	0	6000
Number of yearly inter-modal passengers in a context of an inter-modal agreements	0	Not Available
Number of multimodal passengers using successively rail and air (or air and rail)	Not available	4200000
Number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air	-	5
Number of inter-modal air operators	0	94
Number of inter-modal rail operators	0	1
Number of non-European air carriers proposing inter-modal services	0	58
Total yearly PKT of inter-modal flights	0	Not Available
Total yearly ASKs of inter-modal flights	0	2,37E+11
Access time between each terminal and the airport railway station	Not Available	-
Access time to the airport by car (in minutes) from the city centre	[20,30]	-
Price of rail access journey (in euros)	3,25	-
Time of rail access journey (in minutes)	12	-
Average value of time (for one minute) of passengers accessing the airport by rail	0,32	-

Table 19: Collected data for Frankfurt airport

Data	Airport access	Airport integration
Average value of time (for one minute) of passengers accessing the airport by private car	0,18	-
Daily price of airport parking	21	-
Number of cities that are served by train from the airport for a train journey time not exceeding 3 hours	-	10
Number of airport passengers in transit (to and from a flight)	-	17885000
Number of airport passengers accessing the airport by rail	6132000	-
Number of airport passengers accessing the airport by other transport modes than rail	Not Available	-
Population of cities directly served by train from the airport.	-	21934643
Proportion of passengers using terminal 1	29%	-
Proportion of passengers using terminal 2	71%	-
Percentage of the population of the country that travels yearly by air	-	Not Available
Average number of trips each air passenger makes by year	-	Not Available

Table 20: Collected data for Frankfurt airport

The minimum connecting time between HST arrival and flights departure is 45 minutes in the scope of AiRail inter-modal agreement.

The 12 kilometres between the city centre and the airport can be performed by car in 20 to 30 minutes. The congestion risk factor is then 1,0.

Unfortunately we do not know the percentage of air passengers that are in transit at the airport but we will assume that this percentage is the same than at Paris CDG or London Heathrow airport i.e. 35%.

4.4 Amsterdam Schiphol airport

4.4.1 General presentation

Amsterdam Schiphol airport is located at 15 kilometres south west of Amsterdam city centre. The 42.5 millions of passengers in 2004 of Amsterdam airport were transported by the 386 125 yearly flights arriving or departing from the airport. 100 airlines offer 275 national and international destinations.

The airport can be reached by rail thanks to a suburban rail link, in 20 minutes from Amsterdam Central railway station. Trains are operated by the Nederlandse Spoorwegen (NS) with a frequency of 15 minutes between 6h00 AM and midnight and every hour during the night.

Three different bus operators provide connections to the airport from Amsterdam city centre:

- KLM bus offering an airport line to many hotels of Amsterdam city centre;
- Interliner bus 370 linking the airport to Amsterdam city centre every 30 minutes;

- Airport shuttle connecting every 20 minutes the airport to 55 hotels of the city centre.

In 2002, the proportion of passengers using buses to connect the airport was 8.9 % while the figure for employees was 7.7 %.

The airport is also fully integrated in the regional and international rail network:

- A passenger train station, situated underneath the passenger terminal complex links directly the airport with more than 70% Dutch railroad stations (382 Dutch stations in total). At present, all the busiest 30 stations in the Netherlands (with more than 7500 passengers boarding per day, 54% of total rail traffic) have direct services to Schiphol with the exception of Eindhoven, Arnhem, Den Bosch, Haarlem, Nijmegen, Tilburg, Alkmaar, Gouda, Amsterdam Amstel, Maastricht and Ede-Wageningen. Current plans envisage direct services from Eindhoven, Arnhem, Den Bosch, and Ede when the connection at Duivendrecht is opened at the end of 2005. Trains are operated by the Nederlandse Spoorwegen (NS) which has a concession to operate the Dutch main rail network;
- The train station is operated by international Benelux train that links Schiphol with Antwerp and Brussels (up to 15 departures / day are scheduled) in two hours and three hours respectively;
- «Thalys International», operated by NS with the French and Belgian railways, also uses the station. TGV trains run between the airport and the following cities:
 - The Hague HS, in 20 minutes from the airport;
 - Rotterdam, in 40 minutes from the airport;
 - Berchem Rail Station (Antwerp – Belgium), in 1 hour and 45 minutes from the airport;
 - Midi Rail Station (Brussels) in 2 hours and 20 minutes from the airport;
 - Gare du Nord in Paris, in 3 hours and 50 minutes from the airport.

Thalys trains link the above mentioned cities with a frequency of up to 7 trains per day. They operate high-speed tracks (up to 300 km/h) in the route between Paris and Brussels, but still use low speed track in the Netherlands. The planned 2007 opening of a high-speed link to Rotterdam and Antwerp will considerably shorten journey times to Schiphol from Rotterdam, Belgium and Paris. As an example, travel time between Schiphol and central Antwerp will be 40 minutes. This should make Schiphol airport the first choice of airport for people living in the Antwerp area instead of Brussels Airport.

Aside from having the “Thalys” international partnership with France and Belgium, NS has also an agreement with Deutsche Bahn (DB) to operate international liaisons between Holland and Germany including:

- ICE-international: a joint venture company that operates the high-speed train between Amsterdam Centraal Station, Cologne and Frankfurt;
- Intercity Berlin: international trains running between Amsterdam Centraal Station and Berlin (via Hanover).

Although not serving directly Schiphol airport (suburban NS trains link Schiphol Station with Centraal Station), ICE-international and Intercity Berlin trains are in the scope of the “Rail & Fly Amsterdam” service, an integrated ticketing service for passengers travelling with some partner airlines.

The Rail & Fly Amsterdam service covers the full rail and air trip from any German railway station to their final destination. Passengers use only one ticket for their entire train (including e.g. DB regional trains, ICE, NS suburban trains) and airline journey.

In total, the proportion of passengers using trains to connect the airport was 34.7 % in 2002. For employees, the figure was 13.8 % in 2002.

General information	2004 Values
Total number of yearly passengers in 2004	42 500 000
Total number of destinations proposed by the airport	275
Total number of airlines operating at the airport	100
Total number of rail transport operators operating at the airport	2
Total yearly PKTs supplied by all airlines to and from the airport	Not Available
Total yearly ASKs supplied by airlines to and from the airport	1,7E+11
Total capacity in number of passengers of the airport	83 504 700

Table 21: General information on Schiphol airport

4.4.2 Inter-modal agreements

While no inter-modal agreements exist with regards to the airport access, some airlines have entered into an agreement with the rail to operate “feeder” international trains to Schiphol. There are two agreements to distinguish: “Thalys International” on the Antwerp – Schiphol link and “Rail & Fly Amsterdam” for passengers travelling from Germany.

4.4.2.1 Thalys International

Thalys International has developed a code-sharing agreement with KLM and Northwest on the Antwerp – Berchem – Rotterdam – Schiphol link. This has eliminated all flights by KLM between Schiphol and Antwerp. Passengers travel by rail using an air ticket. The ticket groups the Antwerp – Schiphol link together with a flight departing / arriving from / to the airport. In addition Northwest airlines also has a code-sharing with Thalys International on the Brussels-Midi rail link

However, no airport-style facilities such as hold baggage check-in facilities are provided at the stations of Antwerp – Berchem, Rotterdam and Brussels. Passengers still have to travel with their luggage in the trains and check-in at the airport.

Inter-modal agreement	Airlines	Global reservation	Market share in ASKs at the airport
Thalys International agreement	KLM	X	51%
	Northwest	X	8%

Table 22: Features of Thalys Inter-modal agreements at Schiphol airport

4.4.2.2 Rail & Fly Amsterdam

As well as offering integrated air / rail ticketing services between German towns and German airports, “Rail & Fly Amsterdam” offers integrated ticketing services between Schiphol airport and German towns to passengers of the following airlines: Eva Airways, China Airlines, Garuda Indonesia, Martinair and Air Astana.

Passengers may board several trains from any railway station in Germany to Schiphol station and board their flights without having to buy several tickets for the different transport modes.

However, the agreement does not concern the holding and check-in of baggage. Passengers have still to travel with their luggage in trains and perform check-in at the airport.

Inter-modal agreement	Airlines	Global reservation	Market share in ASKs at the airport
Rail & Fly Amsterdam	Air Astana	X	0,2%
	China Airlines	X	1%
	Eva Airways	X	1%
	Garuda Indonesia	X	1%
	Martinair	X	5%

Table 23: Features of Rail & Fly Amsterdam agreement at Schiphol airport

4.4.3 Inter-modal traffic

4.4.3.1 Thalys International

All air destinations proposed in the scope of the Thalys international agreement are international. Passengers that bought an inter-modal Thalys / air ticket have access to the global international network of KLM and to the destinations that Northwest Airlines reach from Schiphol. In total, this represents about 139 “inter-modal” destinations.

With a frequency of up to 7 trains per day, passengers that ride a train at Antwerp can efficiently connect the inter-modal destinations offered at Schiphol.

4.4.3.2 Rail & Fly Amsterdam

The destinations proposed in the scope of “Rail & Fly Amsterdam” are the following Asian destinations: Bangkok (Thailand), Taipei (Taiwan), Almaty, Atyrau and Astana (Kazakhstan).

ICE high-speed trains run seven times per day on the Amsterdam – Düsseldorf – Cologne – Frankfurt link. The Amsterdam – Hanover – Berlin route, operated by “intercity Berlin” trains, has three daily frequencies.

Travelling time to Schiphol is 2 hours and 24 minutes from Düsseldorf, 2 hours and 47 minutes from Cologne, 4 hours from Frankfurt on ICE-international high-speed trains. On “intercity Berlin” trains, the travelling times are 4 hours 18 minutes from Hanover, and up to 6 hours ½ from Berlin.

4.4.3.3 Competition between air and rail

With regards to the domestic network, there are very few destinations linked with Schiphol as the small size of the country does not make the air competitive against the train. Competition between the “Thalys” (on Antwerp – Schiphol link) and the airlines does not exist either as all flights between Antwerp and Schiphol have been eliminated. Hence, the only domestic destinations that KLM offer from Schiphol are Eindhoven and Maastricht that are not competing with Thalys.

On the contrary, competition between air and rail exists on German destinations that are also proposed in the scope of the Rail&Fly Amsterdam agreement. In particular KLM offers daily flights to 10 German cities: Berlin, Bremen, Cologne, Düsseldorf, Frankfurt, Hamburg, Hanover, Munich, Nuremberg and Stuttgart.

However, only the rail link to Cologne and Düsseldorf, can be considered competitive against the air since their journey time does not exceed 3 hours. The number of daily trains exceeds largely the number of daily flights.

Destination	Number of daily flights to or from the inter-modal destination	Number of daily trains to or from the inter-modal destination
Cologne	6	28
Düsseldorf	10	32

Table 24: Number of daily flights and trains to or from destinations in competition between air and rail

4.4.4 Collected data

Table 25: Collected data for Amsterdam airport, summarised information collected that will be used for building the indicators, differentiated according to the case of airport access and airport integration in the rail network.

Although Regional trains are directly connected to Amsterdam airport, the only existing inter-modal agreements are on international railway links: Thalys and ICE/Intercity Berlin/DB regional trains. As a consequence of the non-existence of agreements concerning the airport access, data relative to inter-modality for airport access are equal to zero.

Data	Airport access	Airport integration
Number of rail transport infrastructures connected to the airport (dedicated rail link, non dedicated rail links, etc.)	1	2
Total capacity in number of passengers of the railway stations	Not Available	Not Available
Minimum connection time between rail and air transport modes (in minutes)	-	90
Total number of inter-modal agreements between air and ground operators	0	7
Number of inter-modal air destinations	0	159
Number of inter-modal rail destinations	0	6002
Number of yearly inter-modal passengers in a context of an inter-modal agreements	0	Not Available
Number of multimodal passengers using successively rail and air (or air and rail)	Not Available	Not Available
Number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service	-	2

by air		
Number of inter-modal air operators	0	7
Number of inter-modal rail operators	0	2
Number of non-European air carriers proposing inter-modal services	0	5
Total yearly PKT of inter-modal flights	0	Not Available
Total yearly ASKs of inter-modal flights	0	1,00E+11
Access time between each terminal and the airport railway station	Not Available	-
Access time to the airport by car (in minutes) from the city centre	Not Available	-
Price of rail access journey (in euros)	Not Available	-
Time of rail access journey (in minutes)	Not Available	-
Average time value of passengers	Not Available	-
Daily price of airport parking	22,5	-
Number of cities that are served by train from the airport for a train journey time not exceeding 3 hours	-	Not Available
Number of airport passengers in transit (to and from a flight)	-	Not Available
Number of airport passengers accessing the airport by rail	Not Available	-
Number of airport passengers accessing the airport by other transport modes than rail	27 552 500	-
Population of cities directly served by train from the airport.	-	9940932
Proportion of passengers using terminal 1	100%	-
Percentage of the population of the country that travels yearly by air	-	Not Available
Average number of trips each air passenger makes by year	-	Not Available

Table 25: Collected data for Amsterdam airport

The minimum connecting time between HST arrival and flights departure is 90 minutes in the scope of the Thalys International inter-modal agreement.

5 Computation and comparisons of inter-modal indicators between considered airports

5.1 Macro level analysis

The objective of the present section is to provide the global picture of the airports' inter-modality both for airport access and airport integration.

Additional information, to be used in a more detailed comparison between airports, are also available in a separate section (§ 5.2).

5.1.1 Airport access

	Category of indicators	Indicator	London Heathrow airport	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Supply	Inter-modal infrastructure	Number of rail infrastructure connected to the airport	2	1	1	1
	Inter-modal operators	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport	55%	0	0	0
	Inter-modal service	Number of inter-modal destinations by air relative to the total number of destinations	84%	0	0	0
		Average daily frequencies of the airport rail access	70	0	0	0
Demand	Demand for inter-modality	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	32%	Not available	Not available	Not available

Table 26: “Macro level indicators” for airport access

Heathrow is the only airport that benefits from inter-modal agreements concerning the access to the airport. This is why, the value of inter-modal operators & services indicators of the other airports is “0”. However, potential to develop inter-modality exists since all the airports have already rail infrastructure connected to the airport.

At Heathrow, it should be noted that inter-modal supply is quite well developed, inter-modal airlines have a non negligible market share at the airport, and most of air destinations (84%) are in the scope of an inter-modal agreement. In addition the 70 daily Heathrow Express trains allow a good coordination with these inter-modal flights.

Finally, rail transportation at Heathrow for accessing the airport represent 32% of the total passengers that have to come and leave the airport. Indeed, bus transportation is quite developed as well and private cars still represent an important proportion too. This may be because the price of a Heathrow Express ticket is very high and the other rail mode – the tube – is not very fast.

5.1.2 Airport integration

	Category of indicators	Indicator	London Heathrow airport	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Supply	Inter-modal infrastructure	Number of rail infrastructure connected to the airport	0	1	2	2
	Inter-modal operators	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport	0%	60%	88%	59%
	Inter-modal service	Number of inter-modal destinations by air relative to the total number of destinations	0%	58%	76%	58%
		Number of inter-modal destinations by rail	0	16	6000	6002
Demand	Demand for inter-modality	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	0%	5%	13%	Not available

Table 27: “Macro level indicators” for airport integration

Heathrow is the only airport among the four airports analysed that is not connected to the national railway infrastructure. Therefore, all the indicators for Heathrow have the value “0”.

As far as the other airports are concerned, only Paris CDG airport is not connected to a regional rail network. This explains why the indicator of the existence of rail infrastructure is 1 for Paris CDG and 2 for Frankfurt and Amsterdam Schiphol airports.

We can note that the market share of inter-modal airlines at Frankfurt airport is high, that can be largely explained by the large number of inter-modal airlines. In addition, the quite high market share of inter-modal airlines at Paris CDG and Amsterdam Schiphol airports can be explained by the

presence of the French and Dutch national airlines among these airlines. Indeed Air France and KLM supply 50% of the total ASKs at CDG and Schiphol airports respectively.

Also, inter-modal services cover a high proportion of the Frankfurt's airport destinations (76%), higher than the other airports (18% higher than at Paris and Amsterdam), which can be associated to a list of 6000 different inter-modal destinations (as a comparison, only 16 rail destinations for Paris).

As the inter-modality supply has the highest levels of demand at Frankfurt, it stimulates the demand from passengers to use both rail and air modes of transportation. While the percentages (13%) is still quite low, it has continuously improved over last years, meaning that passengers are getting more and more interested in multimodal transportation.

Overall, at a macro-level analysis, Frankfurt appears to have the highest levels of supply and demand of inter-modality. This Frankfurt preponderance can be confirmed or mitigated when going deeper in the measurement of inter-modality at airport, what tends to show the importance of also performing a more detailed analysis.

5.2 Detailed analysis

As already mentioned, Heathrow Express is the only inter-modal agreement for airport access that exists. It will then not be possible to have a detailed comparison of the indicators of inter-modal services, operators and demand of London Heathrow airport with other airport cases. Indicators of this airport will then be commented without being able to benchmark between airports.

Nevertheless, this benchmarking will be done in the case of airport integration for which we will compare inter-modal indicators of Paris CDG, Frankfurt and Amsterdam Schiphol airports.

For each computed indicator we indicate the confidence level that is relative to the fact the indicator is "ideal" or "alternative". When the computed indicator is an "ideal" indicator the confidence level is "Good" while when it is an "alternative" indicator the confidence level is "Medium".

5.2.1 Indicators of inter-modal infrastructure

5.2.1.1 Airport access

Heathrow airport is among the four considered airport the one offering the largest choice in terms of rail access but on the same time requires the highest access time between railway stations and airport terminals. This can be explained by the fact that at London Heathrow airport the terminals handling the largest proportion of passengers (Terminals 1 and 3) are the more distant from railway stations while the opposite is true at CDG airport.

Using the two rail access (underground and Heathrow Express) seem to be more interesting than accessing the airport by car and parking it during the travel, if the total duration of the travel is more than 1,6 day. At Paris CDG, airport rail access is more interesting than using the private car when the travel duration exceeds 0,9 day. Below this limit passengers would prefer accessing the airport by car. This difference between both airports is mainly due to a longer rail journey time by rail for accessing London Heathrow compared to Paris airport (the subway link between London and Heathrow is quite slow), and also by the higher risk of congestion inherent to the road transportation system at Paris.

Objectives of indicators	Indicators	Confidence level	London Heathrow airport	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Existence of rail infrastructure in the airport area	Number of rail infrastructure connected to the airport	Good	2	1	1	1
Access time between the inter-modal infrastructure and the terminal	Access times between the airport railway station and the several terminals weighted by the proportion of passengers that can be handled in each terminal	Good	8	4,5	Not Available	Not Available
Rail capacity	Yearly capacity in number of passengers of the railway stations located in the airport area	Good	Not Available	Not Available	Not Available	Not Available
Interest of inter-modal infrastructure for airport users	Travel duration in number of days for which passengers would prefer to access the airport by rail than by using their private car	Good	1,6	0,9	Not Available	Not Available

Table 28: Computed indicators of inter-modal infrastructure for airport access

5.2.1.2 Airport integration

Among the three considered airport only Paris CDG airport is not connected to a regional rail network. This explains why the indicator of the existence of rail infrastructure is 1 for Paris CDG and 2 for Frankfurt and Amsterdam Schiphol airports.

Frankfurt airport is the airport allowing the shortest connecting time between rail infrastructure and terminals with only 45 minutes, what tends to show that the integration between the inter-modal infrastructures is more efficient than in the two other airports.

Paris CDG can be considered as offering a high interest level for airport users by offering 11 rail connections to cities in less than 3 hours.

Objectives of indicators	Indicators	Confidence level	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Existence of rail infrastructure in the airport area	Number of rail infrastructure connected to the airport	Good	1	2	2
Access time between the inter-modal infrastructure and the terminal	Minimum connection time	Good	71	45	90
Rail capacity	Yearly capacity in number of passengers of the railway stations located in the airport area	Good	Not Available	Not Available	Not Available
Interest of inter-modal infrastructure for airport users	Number of cities that are served by train from the airport for a train journey time not exceeding 3 hours	Good	11	Not Available	Not Available

Table 29: Computed indicators of inter-modal infrastructure for airport integration

For summarising if Frankfurt airport provides the best infrastructure indicators in terms of number of inter-modal infrastructures and of access time between the infrastructure.

5.2.2 Indicators of inter-modal operators

5.2.2.1 Airport access

Among the 13 airlines having concluded an inter-modal agreement with Heathrow Express half of them are non-European. This inter-modal product seems then to equally interest airlines independently of their origin. If this number of inter-modal operators seems to be low compared with the 92 airlines operating at the airport, these inter-modal airlines have a non negligible market power (with a medium confidence level) at the airport by supplying more than half of the total level of ASKs.

Objectives of indicators	Indicators	Confidence level	London Heathrow airport
Number of inter-modal operators	Number of inter-modal air operators	Good	13
	Number of inter-modal rail operators	Good	1
	Number of non European airlines proposing inter-modal service	Good	7
Market power	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport	Good	55%

Table 30: Computed indicators of inter-modal operators for airport access

5.2.3 Airport integration

For the three considered airports more than half of the inter-modal operators are non-European. We can explain this attraction of non-European airlines for these inter-modal products by the fact that the cooperation with regional or high-speed trains operators allows them to increase the number of potential passengers that could take their long-haul flights.

With a medium confidence level we can note that the market power of inter-modal airlines at Frankfurt airport is high, that can be largely explained by the large number of inter-modal airlines. In addition, the quite high market power of inter-modal airlines at Paris CDG and Amsterdam Schiphol airports can be explained by the presence of the French and Dutch national airlines among these airlines. Indeed Air France and KLM supply 50% of the total ASKs at CDG and Schiphol airports respectively.

Objectives of indicators	Indicators	Confidence level	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Number of inter-modal operators	Number of inter-modal air operators	Good	8	94	7
	Number of inter-modal rail operators	Good	2	1	2
	Number of non European airlines proposing inter-modal service	Good	5	58	5
Market power	Yearly ASKs of airlines having inter-modal agreements, over the total number of yearly ASKs at the airport	Good	60%	88%	59%

Table 31: Computed indicators of inter-modal demand for airport integration

For summarising, inter-modal products in the scope of airport integration seem to be particularly attractive for non-European airlines. Nevertheless the presence of the national airline among all the inter-modal operators allows a significant market power of these inter-modal airlines on the airport.

5.3 Indicators of inter-modal services

5.3.1 Airport access

Although it is not possible to compare, indicators of inter-modal services of Heathrow Express with those of other inter-modal agreements, they seem to be quite high. Indeed the 13 agreements concern 84% of the proposed destinations to and from the airport that represents 868 flights per day (over the 1368 flights departing and arriving daily). In addition the 70 daily Heathrow Express trains allow a good coordination with these inter-modal flights.

Objectives of indicators	Indicators	Confidence level	London Heathrow airport
Existence of inter-modal agreements	Number of agreements	Good	13
Specificities of inter-modal agreements	Number of characteristics of each agreement weighted by the yearly market share in ASKs of the airline operator summed up over all agreements	Good	1,14
Inter-modal air supply	Number of inter-modal destinations by air relative to the total number of destinations	Good	84%
	Number of daily air frequencies summed up over all inter-modal destinations	Good	868
	Average daily frequencies of the airport rail access	Good	70

Table 32: Computed indicators of inter-modal services for airport access

5.3.2 Airport integration

Among the three considered airports Frankfurt airport is incontestably the one proposing the best indicators of inter-modal services. Indeed, the 95 AiRail and Rail&Fly agreements present the highest indicator of specificities of inter-modal agreement and concern 18% more destinations than the inter-modal agreements at Paris CDG and Amsterdam airports with 959 flights per day (over the 1268 proposed to and from the airport). This large range of inter-modal air destinations can be associated to 6000 different inter-modal rail destinations meaning that passengers coming or going to all cities of Germany are able to fly to and from Frankfurt airport in the scope of an inter-modal agreement.

This high level of indicator of inter-modal rail supply obviously leads to a higher level of competition in terms of number of destinations between air and rail than it can be in the two other airports. Indeed 5 rail destinations (with a journey time not exceeding 3 hours) are in competition with air. Nevertheless the competition in terms of daily frequencies is not so strong than at Paris CDG airport where rail and air almost propose the same level of frequencies. The case of CDG airport indeed differs from the two others since it appears clearly that Air France still proposes numerous frequencies on the two competing destinations (40% of the total air/rail daily frequencies are offered by Air France) while the declared objective of Lufthansa at Frankfurt airport is to substitute as much as possible flight by train. This strategy seems to be the same for KLM since while the number of air/rail competing destinations is the same at Paris CDG and Amsterdam Schiphol airports, the number of air frequencies on these destinations is 20% lesser at Amsterdam.

In general, the comparisons of the various indicators of inter-modal service for Paris CDG and Amsterdam Schiphol airports do not allow to conclude that one of them proposes a better level of inter-modal services. If more inter-modal agreements have been concluded at CDG airport with a

higher indicator of specificities of inter-modal agreements, they concern 375 times more inter-modal rail destinations at Amsterdam than at Paris CDG airport for the same proportion of inter-modal air destinations.

Objectives of indicators	Indicators	Confidence level	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Existence of inter-modal agreements	Number of agreements	Good	11	95	7
Specificities of inter-modal agreements	Number of characteristics of each agreement weighted by the yearly market share in ASKs of the airline operator summed up over all agreements	Good	2,16	2,33	0,69
Intermodal air supply	Number of inter-modal destinations by air relative to the total number of destinations	Good	58%	76%	58%
	Number of daily air frequencies summed up over all inter-modal destinations	Good	698	959	586
Intermodal rail supply	Number of inter-modal rail destinations	Good	16	6000	6002
	Number of daily rail frequencies summed up over all inter-modal rail destinations	Good	204	Not Available	Not Available
Competition between air and rail	Number of destinations offered by rail in the scope of an inter-modal agreement where there is also a service by air	Good	2	5	2
	Number of daily frequencies by air on all competing routes, divided by the total number of daily frequencies (air+rail)	Good	40%	14%	20%

Table 33: Computed indicators of inter-modal services for airport integration

For summarising, inter-modal agreements existing at Frankfurt airport provide better levels of inter-modal services than at Paris CDG or Amsterdam Schiphol airport. If inter-modal services offered at Paris CDG airport seem to be better than at Amsterdam Schiphol airport in terms of number and specificities of inter-modal agreements, they are worse in terms of inter-modal rail

supply.

5.4 Indicators of inter-modal demand

5.4.1 Airport access

Objectives of indicators	Indicators	Confidence level	London Heathrow airport
Number of inter-modal passengers transported	Number of passengers using inter-modal services relative to the total number of airport passengers that are not in transit	Medium	Not Available
Number of multimodal passengers transported	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	Medium	32%
Potential demand for inter-modal service on existing network	Number of passengers of the airport that are not in transit	Good	43 745 000

Table 34: Computed indicators of inter-modal demand for airport access

Among the 43.7 millions of London Heathrow passengers that are not in transit and that have therefore to come and leave the airport, only 32% use rail transport for accessing the airport (with a medium confidence level).

5.4.2 Airport integration

Unfortunately we do not have many values of indicators of inter-modal demand due to the gap of necessary data. Hence if we have no information on the number of inter-modal passengers, we are able to compare the number of multimodal passengers i.e. the number of passengers using successively rail and air transport (whether they benefit from an inter-modal agreement or not) between Paris CDG and Frankfurt airports. With a medium confidence level we can note that the proportion of multimodal passengers is higher at Frankfurt airport. The airport station at Frankfurt is indeed not only connected to the German high-speed rail network, but also to the classic train network. The larger choice in terms of rail transport mode but also in terms of number of air/rail possibilities proposed in the inter-modal agreements can justify this higher percentage compared to Paris CDG. Nevertheless, we can note that both percentages remain very low, meaning a low multimodal demand.

Objectives of indicators	Indicators	Confidence level	Paris CDG airport	Frankfurt airport	Amsterdam Schiphol airport
Number of inter-modal passengers transported	Number of passengers using inter-modal services relative to the total number of airport passengers that are not in transit	Medium	Not Available	Not Available	Not Available
Number of multimodal passengers transported	Number of passengers using successively rail and air relative to the total number of airport passengers that are not in transit	Medium	5%	13%	Not Available
Potential demand for inter-modal 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	Good	7,8E+06	Not Available	Not Available
Potential demand for inter-modal 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 by air multiplied by the average number of trips each person makes	Good	Not Available	Not Available	Not Available

Table 35: Computed indicators of inter-modal demand for airport integration

For summarising, if the demand of multimodal passengers is higher at Frankfurt than at Paris CDG airport, both levels of demand are low.

6 Concluding remarks

Four categories of indicators have been chosen, three of them measuring supply (inter-modal infrastructure, inter-modal operators and inter-modal services) and one measuring demand (inter-modal demand).

For each of these categories, indicators related to airport access have been differentiated from indicators of airport integration in the regional or national network of other transport modes. Each time it was possible, when difficulties have been identified for collecting the necessary data for computing the indicators, alternative indicators providing less accurate information than the first defined indicators but being more easily computable have also been defined. Among all these indicators we have highlighted one or two per category of indicator that allow to give a broad picture of the inter-modality at airport. This report proposes therefore two level of analysis of the measurement of inter-modality at airport:

- A macro-level analysis with representative indicators of each of the four categories of indicators;
- A detailed analysis with all the proposed indicators.

Four airports where inter-modal agreements exist have then been benchmarked thanks to concrete computations of these indicators. The considered airports are Paris CDG, Frankfurt, Amsterdam Schiphol and London Heathrow airports.

Heathrow being the only airport where inter-modal agreements exist for airport access, it was not possible to compare indicators of inter-modal services, operators and demand of this airport with other airport cases. Indicators of this airport have then been commented without being able to benchmark between airports.

Nevertheless, this benchmarking has been done in the case of airport integration for which we have compared inter-modal indicators of Paris CDG, Frankfurt and Amsterdam Schiphol airports. At a macro-level analysis Frankfurt appears to have the highest levels of supply and demand of inter-modality. But when performing a more detailed analysis of all the proposed indicators we observe that if Frankfurt airport provides the best infrastructure indicators in terms of number of inter-modal infrastructures and of access time between the infrastructures, Paris CDG airport offers a high level of interest for airport users in terms of available rail destinations. The good performance of Frankfurt airport is also tangible in terms of inter-modal services since inter-modal agreements existing at this airport provide better levels of inter-modal services than at Paris CDG or Amsterdam Schiphol airport. If inter-modal services offered at Paris CDG airport seems to be better than at Amsterdam Schiphol airport in terms of number and specificities of inter-modal agreements, they are not as good in terms of inter-modal rail supply.

Unfortunately the gap of information on the number of inter-modal passengers (i.e. the number of passengers travelling in the scope of an inter-modal agreement) prevents us from computing indicators of demand of inter-modal passengers. However, the computation of indicators of the demand of multimodal passengers (whether they benefit from an inter-modal agreement or not) allow us to note that the demand of multimodal passengers is low as well at Frankfurt as well as at Paris CDG airport and is higher at Frankfurt airport.

As a consequence, the detailed analysis of the indicators tends to confirm the good level of inter-modality at Frankfurt airport already shown by the macro-level analysis. This detailed analysis indeed help to check that this good level generally exists when considering all the aspects of inter-modality that can be measured.

For concluding, we have defined these indicators of airport inter-modality so as they provide the most accurate information as possible in order to evaluate the level of inter-modality at the airport as well as to compare the level of inter-modality of different airports. Nevertheless, an efficient use of them

would require collecting all the necessary data while some of them are not public. This gap of data remains the main obstacle to the use of all these indicators as measures of inter-modality levels.

Annex A : Estimation of rail access time to Paris CDG airport

The city of Paris is divided into 20 “arrondissements” (districts). Each arrondissement is connected to the subway train network known as “metro”. In addition, there are five suburban “RER” (Réseau Express Régional) lines serving a certain number of “metro” stations and connecting Paris with the suburbs.

CDG airport is served by one of the five RER lines, RER B which stops at 7 stations in Paris. Four of these stations are interconnected with the “metro” network. There are two stations at CDG, Charles-de-Gaulle 1 for Terminals 1 and 3 and Charles-de-Gaulle 2 for Terminal 3.

Travel times to the airport vary in function of the departing “arrondissement” and also the airport terminal. In order to compute an average journey time between the city of Paris and the airport, the following parameters have been taken into account:

- for each arrondissement, the main metro / RER station from where rail journey starts;
- the average walking time to reach the station;
- the travel time from the metro station to the final RER B destination, i.e. CDG airport Terminal 1 / Terminal 3 station or CDG airport Terminal 2 station. The total travel time includes metro journey if any, transfer between the metro and the RER if any and RER travel times;
- for each terminal, the average walking time from RER B station to airport’s terminal.

The following table presents for each arrondissement the values – in minutes – of the above-listed parameters.

Arrondissement	Population	Metro / RER station	Walking time: home -> metro/RER station	Rail journey: -> CDG T1/T3 station	Rail journey: -> CDG T2 station	Walking time: -> T1	Walking time: -> T2	Walking time: -> T3
1 st	16888	Châtelet	8	31	33	10	3	8
2 nd	19585	Bourse	6	45	47	10	3	8
3 rd	34248	Arts&Métiers	8	46	48	10	3	8
4 th	30675	Saint-Michel	8	33	35	10	3	8
5 th	58849	Luxembourg	7	41	43	10	3	8
6 th	44919	Saint-Sulpice	6	49	51	10	3	8
7 th	56985	Solferino	7	49	51	10	3	8
8 th	39314	Madeleine	7	44	46	10	3	8
9 th	55838	Richelieu	4	36	38	10	3	8
10 th	89612	Gare de l'Est	5	38	40	10	3	8
11 th	149102	Voltaire	3	51	53	10	3	8
12 th	136591	Dugommier	5	51	53	10	3	8
13 th	171533	Place d'Italie	3	53	55	10	3	8
14 th	132844	Denfert	8	39	41	10	3	8
15 th	225362	Vaugirard	6	57	59	10	3	8
16 th	161773	Henri-Martin	8	57	59	10	3	8
17 th	160860	Rome	5	45	47	10	3	8
18 th	184586	Simplon	6	38	40	10	3	8
19 th	172730	Laumière	7	36	38	10	3	8
20 th	182952	Gambetta	3	57	59	10	3	8

Average journey time (weighted by the population per arrondissement)	5.56	47.48	49.48	10	3	8
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From the table, it is possible to estimate an average journey time for the access to the terminals of CDG airport from Paris city. It is 63 minutes for the link Paris – CDG 1, 61 minutes for the link Paris – CDG 3 and 58 minutes for the link Paris –CDG 2.

Annex B : Estimation of rail access time to London Heathrow airport

London urban area is split into 36 boroughs. Each borough is connected to the subway train network known as the “tube” or underground, which comprises 10 lines in total.

Heathrow airport is served by one of the underground lines, the Piccadilly line. At present, only terminal 1/2/3 is served as the station at terminal 4 has been closed until September 2006 due to the works that are taking place for the construction of a fifth terminal, terminal 5. Replacement bus services connect the underground station of Hatton Cross with terminal 4.

In addition, the airport is also served by a dedicated high speed link – Heathrow Express – from Paddington station. Travel time is 15 minutes to Heathrow 1/2/3 or 20 minutes to Heathrow 4. Paddington station is connected with the underground network via the following lines: Bakerloo, Circle, District and Hammersmith.

Average total journey times to the airport vary in function of the departing “borough” and also the airport terminal. In order to compute an average journey time between London and the airport, the following parameters have been taken into account:

- for each borough, the main tube station from where rail journey starts;
- the average walking or bus time to reach the station (tube station or Paddington station in case the passenger selects the Heathrow Express link to connect the airport);
- the travel time from the tube station to the terminal, i.e. Heathrow terminals 1,2 and 3 or Heathrow terminal 4. The total travel time includes: the tube or Heathrow Express travel times, the transfer between different tubes/Heathrow Express lines, and the walking time to reach the terminals from the Piccadilly or Heathrow Express airport stations.

The following table presents for each borough the values – in minutes – of the above-listed parameters.

Borough	Population	Tube station	Walking / bus time: home -> tube station	Rail journey (by tube only): - > T1/T2/T3	Rail journey (by tube only): - > T4	Walking / bus time: home -> Paddington station	Rail journey (by tube & Heath. Express) - > T1/T2/T3	Rail journey (by tube & Heath. Express) -> T4
City	7185	Old Street	0	63	75	33	15	20
Westminster	181286	Victoria	0	43	55	23	15	20
Kensington	158919	S Kensington	11	40	52	34	15	20
Chelsea		S Kensington	16	40	52	34	15	20
Hammersmith	165242	Hammersmith	13	32	44	24	15	20
Fulham		Hammersmith	22	37	49	21	15	20
Wandsworth	260380	Wandsworth	11	54	66	47	15	20
Lambeth	266169	Westminster	21	47	59	41	15	20
Southwark	244866	Southwark	0	50	62	18	15	20

Tower Haml.	196106	Crystal Pala.	14	66	78	78	15	20
Hackney	202824	Manor House	24	65	77	59	15	20
Islington	175797	Angel	6	57	69	37	15	20
Camden	198020	Mornington	12	56	68	48	15	20
Brent	263464	Apeltorn	37	35	47	N/A	N/A	N/A
Ealing	300948	S Ealing	19	22	34	18	15	20
Hounslow	212341	Hounslow E	19	13	25	N/A	N/A	N/A
Richmond	172335	Richmond	0	48	60	N/A	N/A	N/A
Kingston	147273	Hatton Cross	24	11	23	N/A	N/A	N/A
Merton	187908	Wimbledon	18	70	82	73	15	20
Sutton	179768	Hatton Coss	58	11	23	N/A	N/A	N/A
Corydon	330587	Vuctoria	25	73	85	77	15	20
Bromley	295532	Bromley S	16	92	104	N/A	N/A	N/A
Lewisham	248922	Monument	31	61	73	53	15	20
Greenwich	214403	Monument	26	61	73	52	15	20
Bexley	218307	Elephant Cas.	51	87	99	77	15	20
Havering	224248	Hornchurch	30	120	132	92	15	20
Barking	163944	Barking	0	88	100	57	15	20
Redbridge	238635	Redbridge	0	85	97	50	15	20
Newham	543891	Canning town	24	85	97	78	15	20
Waltham	218341	Blackhorse R.	19	78	90	71	15	20
Haringey	216507	Manor House	31	71	83	41	15	20
Enfield	273559	Grange Park	5	93	105	65	15	20
Barnet	314564	High Barnet	17	103	115	85	15	20
Harrow	206814	Rayners Line	28	67	79	78	15	20
Hillingdon	243006	Hillingdon	0	51	63	N/A	N/A	N/A

Average journey time (weighted by the population per borough)	18.79	62.49	74.49	44.07	15	20
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Note: In some cases, it is not relevant for the passenger to travel to Heathrow via the Heathrow Express since the borough where rail journey starts is very far from Paddington Station (e.g. cases of western boroughs located close to Heathrow Airport). In those cases, the value “N/A” figures in the table.

From the table, it is possible to estimate an average journey time for the access to terminals of Heathrow airport using tubes only or connecting Heathrow Express trains at Paddington. It is 81 minutes for the link London – Heathrow T1/T2/T3 by tubes only or 59 minutes with Heathrow

Express, 93 minutes for the link London – Heathrow T4 by tubes only or 64 minutes with Heathrow Express.