DATASET2050

"Data driven approach for a Seamless Efficient Travelling in 2050"

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Deliverable 2.1
"Data requirements and acquisition"

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Abstract

The purpose of this document, Deliverable 2.1, is to describe the sources of data required by the H2020 coordination and support action DATASET2050. Data requirements have been categorised into seven broad groups to support WP3 and WP4: demographic; passenger demand; passenger type; door-to-kerb; kerb-to-gate; airside capacity and competing services. The current scenario is well supported by existing datasets, however the two future scenarios require modelled data.

With prior agreement, this report has been delivered in Month 14 (January 2016), slightly later than scheduled in the Grant Agreement.

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1. Introduction

1.1 DATASET2050 introduction

DATASET2050, "DATA-driven Approach for Seamless Efficient Travelling in 2050" is a Coordination and Support Action (CSA) funded by the European Commission, under H2020 Call MG.1.7-2014 "Support to European Aviation Research and Innovation Policy", Grant Agreement no: 640353. The Coordination and Support Action is coordinated by Innaxis, with EUROCONTROL, and the University of Westminster and Bauhaus Luftfahrt as partners. DATASET2050 was launched in December 2014 and will last 36 Months. The key highlights of DATASET2050 are the following:

- The main aim is for the CSA results to provide useful insights into the door-to-door European travel paradigm for the current, 2035 and 2050 transport scenarios, through a cutting edge data science approach.
- DATASET2050 puts the passenger at the centre, paving the way for a seamless, efficient door-to-door travelling experience. The main focus is placed on analysing how the European transport supply profile (capacity, connections, business models, regulations, intermodality, processes, infrastructure) could adapt to the evolution of the demand profile (customers, demographics, passenger expectations, requirements).
- Through expert application of state-of-art predictive analytics, modelling, statistical analyses and data visualisation, with an examination of multimodal data, the executed analyses will enable the identification of European transport bottlenecks and weak areas across the different scenarios. These findings will serve as a basis for the development of intermodal transport concepts, identifying possible solutions for current and predicted shortcomings. The insights gained through the project's approach will highlight research needs towards the four hour door-to-door goal formulated by ACARE.
- DATASET2050 partners will be supported by an Advisory Board, comprised of top European transport Entities (universities, policy makers, airlines, industry, research Institutes, GIS and inter-/multimodal entities) with major inputs into European strategy agendas.
- The comprehensive dissemination and communication plans aim to ensure efficient circulation of the results among key European transport policy makers and stakeholders.

1.2 WP2 and Deliverable 2.1 context

D2.1 is the first deliverable of WP2 "Data driven architecture". D2.1 is the very first technical deliverable of the CSA. D2.1 tasks are of a crucial importance within DATASET2050 for different reasons:
- It lists the sources of data required by DATASET2050;
- It documents the data requirements, which have been categorised into groups;
- Its outcomes are crucial to support WP3 and WP4 and all the subsequent data-driven tasks of the project.

It is important to note that whilst the current scenario will be supported by existing datasets, the two future scenarios require modelled data.

2. Overview Data Requirements

2.1 Scope

The second goal of the Flightpath 2050 (European Commission, 2011a) "Meeting societal & market needs" states that "90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours. Passengers and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on-time." The DATASET2050 Coordination and Support Action focuses on analysing this goal to shed light on the current situation in air transportation and to identify bottlenecks hindering the system to fully achieve its potential. The CSA also focuses on the long term and potential future scenarios that can help achieve (or not) this goal.

However, before the actual data collection process starts it is important to define the terminology of this Flightpath goal, e.g. what travellers and door-to-door exactly means and what it is to reach the final destination smoothly. The goal also mentions predictability and on-time, however precise figures need to be stated to ensure the goal is accomplish. Even more, in the long term even the geographical scope and what we can understand by Europe, traveller, transfer and transport modes could change, as new technologies and advances become available. In this section we define the overall scope of the project and data.

Travellers
The scope of the DATASET2050 CSA is focused on air travellers understood as all journeys for which air transport has any contribution, even when the air segment is significantly smaller than ground/sea transport, e.g. regional flights connecting remote villages for which the door-to-airport segment takes longer than the gate-to-gate segment or even in some cases where airport procedures are longer than the actual flight due to overcrowded procedures and queues.

Four hours door-to-door (4HD2D)
The Flightpath 2050 societal and market goal defines a maximum door-to-door journey of 4 hours for 90% of the travellers. In most cases the door-to-door itineraries can be broken down into several steps. In the DATASET2050 CSA door-to-door journeys are divided into the following segments:

* door-to-kerb, multi-modal, public/private transport;
* kerb-to-gate, includes airport processes, check-in, baggage drop-off, security, immigration and boarding;
* gate-to-gate, from boarding to alighting (with connections), including off-block, taxiing-out, take-off, route, landing, taxiing-in and in-block;
* gate-to-kerb, from alighting to luggage reclaim, immigration and customs;
* kerb-to-door, multi-modal, public/private transport.

Geographic scope of Europe
The EU's enlargement policy acknowledges that none of the candidate or potential candidate countries will be ready to join the EU before the current Commission's mandate expires in 2019 (European Commission, 2015a). The scope of the project is to focus mainly

on the current scenario (2014), whilst mid-term (2035) and future (2050) scenarios will be exploratory research. It is out of the project's scope to assess which countries will have completed the EU accession process or when.

DATASET2050 will focus on journeys within 32 European countries – the current EU-28 member states plus the four European Free Trade Association countries (Table 1 and Figure 1). Note that Schengen Agreement cooperation will be included, though no expansion of the current border-free area will be assumed.

Table 1. Countries in scope

EU-28 and EFTA countries			
Austria (S)	Finland (S)	Lithuania (S)	Slovenia (S)
Belgium (S)	France (S)	Luxembourg (S)	Spain (S)
Bulgaria	Germany (S)	Malta (S)	Sweden (S)
Croatia	Greece (S)	Netherlands (S)	United Kingdom
Cyprus	Hungary (S)	Poland (S)	Iceland (EFTA; S)
Czech Republic (S)	Ireland	Portugal (S)	Liechtenstein (EFTA; S)
Denmark (S)	Italy (S)	Romania	Norway (EFTA; S)
Estonia (S)	Latvia (S)	Slovakia (S)	Switzerland (EFTA; S)

EFTA: European Free Trade Association countries
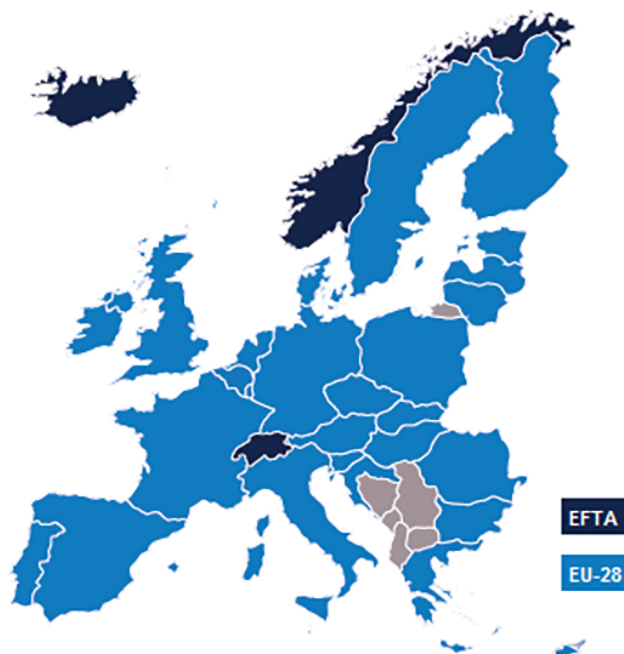**S:** Schengen Agreement countries

Figure 1. Countries in scope

Source: adapted from EFTA (2014)

Time scope
The project will consider three time frames: current with two future scenarios aligned with the Strategic Research and Innovation Agenda (SRIA) roadmap (ACARE, 2012).

DATASET2050 will particularly focus on the current scenario (2014), for which data, facts and figures are available, whilst the medium-term (2035) and long-term (2050) scenarios will be exploratory research. Note that 2035 and 2050 are used as they align with SRIA roadmap future timescales, however they can be read as 203*x* and 205*x*.

Overview of DATASET2050 assumptions

With the lack of any standard interpretation of the 4 hours door-to-door Flightpath 2050 goal, Table 2 provides an overview of the high level assumptions currently being used by this project.

Table 2. High level four hour door-to-door assumptions

Case	Assumption for all scenarios
Travellers	Passenger journeys only are considered; i.e. freight transport is excluded.
Air travel as a mode	All European passenger journeys for which commercial air transport has any contribution.
Journey time	Realistic distribution of journey times including buffer times consistent with the corresponding scenario will be used door-to-door.
Aircraft	Passenger journeys must include the use of commercial passenger aircraft; i.e. private aircraft and personal air vehicles (PAVs) are excluded if the only air transport mode in a journey.
Geographic coverage	Passenger journeys within 32 European countries: current EU member states (EU-28) plus Iceland, Liechtenstein, Norway and Switzerland (EFTA); EU candidate countries such as Montenegro and Turkey, and member states' overseas territories are excluded. The door-to-door aspect of passengers travelling into this geographic zone from outside Europe will commence at the point of entry (e.g. the arrival airport), and conversely for passengers leaving this zone will finish at the point of exit.
Schengen Agreement	The existing border-free area will be assumed to operate as currently (2014).
Scenario timescale	Current scenario: 2014; Medium-term scenario: 2035; Long-term scenario: 2050.

2.2 Data requirements

One fundamental cornerstone of the data-driven methodology in DATASET2050 is to define a set of data requirements, which can enable research on European passenger mobility in the door-to-door context. Data requirements in DATASET2050 are either applied on existing data or recommendations for future data sources.

To better understand the data requirements it is necessary to set the following scope of the European mobility model:

- Each journey can be divided into five phases: door-to-kerb (urban), kerb-to-gate (airport), gate-to-gate (airside), gate-to-kerb (airport), kerb-to-door (urban);
- Each phase has its own data requisites: demand (i.e. WP3) and supply (i.e. WP4);
- The data requirements have been grouped into seven broad categories: demographic, passenger demand, passenger type, door-to-kerb, kerb-to-gate, airside capacity and competing services;
- There are three time scenarios to be explored: current situation, mid-term and long-term.

Previous combinations give a total of 5 phases x 2 demand/supply x 3 time gaps to be filled. However not all combinations can be explored using the same data-driven approach. Especially in the temporal scale; data for the current situation should be mostly quantitative, whilst any data for mid-term and long-term scenarios would be mostly qualitative.

As most of the data sets are limited in scope (e.g. local studies) it is important to focus on data compatibility on the overlapping sets as well as data extrapolation. The use of clustering techniques with known data-to-group elements (e.g. passengers, airports, etc.) into similar characteristics helps to extrapolate data, however these techniques also create data requirements regarding the scope, coverage and compatibility. Also data sets need to be time compatible, that is, data sets should share compatible time frames and similar levels of aggregation.

Given the number of data sources and data transformations nowadays, data provenance is another key element to be considered in each data set. Many available data sets are aggregation of several sources and many times it is not possible to track back the original source of the data and its reliability.

2.2.1 Data requirements scenarios

There are three scenarios to be explored: current situation (2014), mid-term (2035), long-term (e.g. 2050);

Each scenario has a different granularity when modelling:
- Current situation will be analysed using quantitative metrics by using available data and filling the gaps with the simulation engine – detail level down to single passenger itineraries;

- Mid-term scenario will be more a combination of an updated version of the current transport system (including future traffic forecasts) and an exploratory approach exercise, combining quantitative and qualitative analysis – detail level to passenger flows, trends, with a similar transport system;
- Long-term scenario will be fully exploratory research, based on future trends, qualitative studies and more futuristic transport concepts.

Note that the objective is not to forecast, but rather assess current and future scenarios.

2.2.2 Data requirements modelling

When no data are available or there is a need to fill the gaps in the existing datasets, a European mobility model would be used. However, the model is a support tool to derive data that are not directly available, not the main focus of the CSA.

Key elements of the model affecting data requirements:

- The model uses mainly detailed (low granularity) data; Network Operation Plan, passenger itineraries, etc.;
- It can also accept a degree of uncertainty on the data, able to incorporate statistics and produce best proximate answer;
- Data format, availability, provenance are crucial tasks that have been tackled in current deliverable.

Data requirements and grouping from demand/supply are summarised below. The individual data sources identified so far are discussed in Section 3.

Table 3. Summary of data groups

Data groups	Demand/Supply	Examples
Demographic	Demand (indirect)	- population (urban/rural) - demographics - income *i.e. a non-transport macro description of population characteristics*
Passenger demand	Demand (direct)	- passenger modal share - passenger traffic flows - passenger access to transport modes *i.e. an estimate of passenger demand within Europe*
Passenger types	Demand (indirect)	- journey purpose - passenger type, including mobility - passenger itinerary *i.e. to help define archetypical passengers*
Door-to-kerb (and kerb-to-door)	Supply	- time to and from airport (per airport) *i.e. an estimate of the time from door-to-airport kerb and airport kerb-to-door*

Data groups	Demand/Supply	Examples
Kerb-to-gate (and gate-to-kerb)	Supply	• time between kerb and gate (per airport) • minimum connecting times *i.e. an estimate of the time from kerb-to-gate and gate-to-kerb*
Airside capacity	Supply	• airline schedules • traffic (flight) data • airport infrastructure capacity • airspace capacity *i.e. system capacity*
Competing services	Demand / supply	• competing mode • competing technology *i.e. development of high-speed rail network and travel substitution effects due to future technologies*

3. Data Sources and availability

This section outlines the individual data sources that have been identified within the seven broad data groups. DATASET2050 requires both detailed data (e.g. multiple data fields per flight) as well as less-precise, high-level information (e.g. forecast population growth). Large datasets are being sourced from data providers, contrasting with specific figures found through the literature review within published articles. Note that one source may provide information that is useful across journey phases, thereby a source may overlap data groups.

This is an on-going task – additional sources are expected to furnish data for some of the current data gaps. Table 4 provides an overview of current data availability for the key data types within each of the seven groups for the three scenarios. In some cases, data purchase costs may prohibit the use of available datasets.

Table 4. Overview of data availability for each scenario

Data groups	Scenario		
	Current (2014)	Mid-term (2035)	Long-term (2050)
Demographic:			
General and regional statistics	Green	Green	Green
Economy and finance	Green	Green	Green
Population and social conditions	Green	Green	Green
Industry, trade and services	Green	Green	Green
Passenger demand:			
Passengers by mode	Green	Amber	Amber
Passenger requirements	Green	Red	Red
Connectivity	Green	Red	Red
Future strategies by mode	N/A	Green	Green
Passenger type:			
Passenger profiles	Green	Amber	Red
Passenger behaviour	Green	Red	Red
Passenger en-route requirements	Green	Amber	Red
Door-to-kerb:			
Modal share	Green	Amber	Red
Catchment area	Amber	Red	Red
Kerb-to-gate:			
Check-in time profile	Amber	Red	Red
Security screening time	Amber	Red	Red
Exit time profile	Amber	Red	Red
Immigration queuing time	Amber	Red	Red
Airside capacity:			
Airline schedules	Green	Red	Red
Flight and environment data	Green	Red	Red
Airport capacity	Green	Amber	Red
Competing services:			
Air-rail competition	Green	Red	Red
Competing technology	Red	Amber	Amber

Green: data available, e.g. suitable dataset(s) or forecasts exist
Amber: limited data/information available, e.g. partial data coverage or scenario description
Red: data/information unavailable or coverage unknown

3.1 Demographic

This section outlines and describes a range of data references that are essential for the establishment of passenger demand profiles, both within a current and future horizon. It includes data on passenger demographics such as age, sex or income. Furthermore, sources are described which contain information on education, tourism, or the business environment. The information obtained in this section serves as the basis to identify different passenger types and according travel behaviour. Within the description of each data source the different parameters are outlined as well as their availability for current and future scenarios.

3.1.1 European Commission

Source:	Eurostat
URL:	http://ec.europa.eu/eurostat/
Availability:	Free of charge

The Eurostat dataset can be obtained free of charge and it covers data starting in 1990, although not for all available datasets. The Eurostat data is clustered into the following categories: (1) general and regional statistics, (2) economy and finance, (3) population and social conditions, (4) industry, trade and services, (5) agriculture and fisheries, (6) international trade, (7) transport, (8) environment and energy, and (9) science and technology. With regards to the required demographic data, categories (1), (2), (3) and (4) and within these specific indicators are relevant and are described in more detail below. Most of these datasets do not contain any forecasts.

Type of data	Category	Coverage and forecast	Description
Population and area	(1), (3)	1990-2014, forecast up to 2080	Population data by region, age, sex and NUTS2 region, also includes information on demographic change.
Urbanisation	(1)	1990-2015	Population structure for cities, statistics on education, labour markets, economy and finance, transport, culture and tourism on city level/metropolitan region level, urban-rural population (e.g. population density).
Education statistics	(1), (3)	2013-2014	Participation in education and training as well as respective outcomes (by education level, sex, age group).
Science and technology statistics	(1)	1981-2013 1994-2008	R&D expenditure and personnel. Employment in high technology sectors (by NUTS2 region, sex, type of occupation).
Structural business statistics	(1), (4)	2008-2013	Number of local units, persons employed, wages and salaries by NUTS2 regions.
Business demography	(1), (4)	2004-2014	Statistics by legal form and by size class, by regions (NUTS3 level).

Type of data	Category	Coverage and forecast	Description
Tourism statistics	(1), (4)	1990-2014	Occupancy of tourism establishments, capacity of tourist accommodation establishments, data on employment in the accommodation sector.
		1994-2014	Participation in tourism by socio-demographic characteristics of the tourist (sex, age group, education, household income).
		1994-2014	Number of trips (by socio-demographic of the tourist, by country/world region).
		1990-2014	Expenditure on tourism trips (by purpose, length of stay, by country/world region/destination).
Labour market	(1), (3)	1995-2014	Information on earnings by economic activity and occupation.
Information society statistics	(1)	2002-2014	Computers: availability and use; internet: level of access, use and activities (e.g. internet purchases by individual).
Gross domestic product	(1), (2)	1975-2014	Gross domestic product at market prices (by country).
Income and living conditions	(3)	1995-2014	Income: Distribution of income by income groups, by sex and age groups, by household type.
		2003-2014	Living conditions: Distribution of household types and household size, distribution of population by household type and size, by education level; distribution of population by degree of urbanisation, dwelling type and income group; personal well-being indicator.
Quality of life indicators	(3)	different for each indicator (see above)	Quality of life is described by different indicators including material living conditions (e.g. income, housing), productive or main activity (e.g. quantity and quality of employment), health (e.g. life expectancy, access to health care), education (e.g. competences and skills), leisure and social interaction (e.g. access to leisure activities), economic and physical safety (e.g. debt, crime rates), governance and basic rights (e.g. institutions and public services), natural and living environment (e.g. pollution), overall experience of life (e.g. meaning and purpose).

3.1.2 World Bank

Source:	World Bank Open Data
URL:	http://data.worldbank.org/
Availability:	Free of charge

The data from the World Bank is available free of charge and structured according to several categories. From these categories those indicators are extracted which are relevant for the depiction of different passenger profiles.

Type of data	Coverage and forecast	Description
Rural population	1981-2015	Population living in rural areas (by country).
Urban population	1981-2015	Population living in urban areas (by country).
Population	1981-2015	Population growth (annual %) is the annual population growth rate, population includes all residents regardless of legal status or citizenship (except for refugees not permanently settled in the country of asylum); data on the population structure (share of population within the different age groups: ages 0-14, 15-64, 65 and above; % of total population).
Business environment	2013-2014	The indicator "ease of doing business" ranks economies from 1 to 189 (first place being the best), business operations are facilitated by a beneficial regulatory environment, 10 topics are included in the index.
	2004-2012	The indicator "new businesses registered" depicts the number of new limited liability corporations registered in each calendar year.
GDP	1981-2015	GDP (current USD) denotes the gross value added plus any product taxes and minus any subsidies not included in the value of the products. GDP per capita (current USD) (GDP/midyear population). GDP growth (annual %).
Labour market	1981-2013	Unemployment is the share of the labour force that is without work but available for employment, data available for male/female/total and also including long-term unemployment.
	1990-2013	Labour force (total) is the amount of people above 15 including both employed and unemployed.
	1981-2013	Employment in industry (female/male) or in services (female/male); industry includes mining and quarrying (including oil production), manufacturing, construction, and public utilities (electricity, gas, and water); services include wholesale and retail trade and restaurants and hotels; transport, storage, and communications; financing, insurance, real estate, and business services; and community, social, and personal services.
Education	1981-2014 (only country specific)	Literacy rate (adult total, % of people ages 15 and above).

Type of data	Coverage and forecast	Description
Migration and refugees	1981-2012 (5 year estimate)	Net migration contains data on the total number of immigrants minus the annual number of emigrants, including both citizens and non-citizens.
	1990-2014	Refugee population (by country or territory of asylum, by country or territory of origin).
Internet and mobile phones	1990-2014	Internet users (per 100 people).
	1981-2014	Mobile cellular subscriptions (per 100 people).

3.1.3 United Nations

Source:	UNdata
URL:	http://data.un.org/
Availability:	Free of charge

The United Nations publish a range of datasets which can all be accessed publicly and include statistics on (1) commodity trade, (2) energy, (3) environment, (4) food and agriculture, (5) gender, (6) global indicators, (7) greenhouse gas inventory, (8) human development indices, (9) indicators on women and men, (10) industrial development, (11) industrial commodities, (12) international finance, (13) labour market, (14) millennium development goals, (15) children's well-being, (16) different databases on health aspects, (17) demographic statistics, (18) world population prospects, (19) telecommunication/ICT indicators and (20) tourism data. The data relevant for passenger profiles is outlined in the following table.

Type of data	Name of dataset	Coverage and forecast	Description
Population	World Population Prospects (the 2012 revision) Global Indicator Database UNSD demographic statistics	1950-2100	Population and respective growth rate (by country; different future scenarios available).
		1950-2100	Population density (per square km).
		1950-2100	Population age groups (by country).
		1950-2030	Share of urban and rural population.
		1995-2012	Population groups (by literacy, age, sex, urban/rural residence).

Type of data	Name of dataset	Coverage and forecast	Description
Labour, education and gender	Gender Info	1987-2005	Adult literacy rate (by male/female, in percent of total population, by country).
		1985-2005	Female/male ratio of population (by country, by age group).
		1990-2005	Employment in industry and services (by country).
		1985-2004	Rural and urban population (by country).
		1990-2014	Gender parity index in primary/secondary/tertiary enrolment (by country).
Communication	Global Indicator Dataset	1960-2013	Mobile cellular telephone lines per 100 inhabitants (by country).
	World Telecommunication/ICT Indicators Database	1960-2013	Internet users (in percent, by country).
Economic indicators	Global Indicator Dataset National Accounts	1960-2014	GDP (at current USD prices, by country).
		1970-2013	GDP per capita (at current USD prices, by country).
		1961-2014	GDP growth (by country).
		1946-2014	Household spending (by country), data available for spending on different items (e.g. recreation and culture, communication).
Transport	Global Indicator Dataset	1995-2012	Number of passenger cars (by country).
Demographic statistics	UNSD Demographic Statistics	1970-2014	City population (by city, female/male, type of city).
			Foreign population (by country of citizenship, age, sex).
			Households by age and sex (by reference person and size of household).

Type of data	Name of dataset	Coverage and forecast	Description
Tourism and migration	World Development Indicators World Tourism Data	1962-2012 1995-2014	Net migration (by country). Information on tourists: arrivals and departures, expenditure in the destination country (and other countries), by country.

3.1.4 Organisation for Economic Co-operation and Development

Source:	OECD.Stat
URL:	http://stats.oecd.org/
Availability: Free of charge	

The Organisation for Economic Co-operation and Development (OECD) publishes data for OECD countries and selected non-member countries. The datasets are structured according to 22 different themes including (1) general statistics, (2) agriculture and fisheries, (3) demography and population, (4) development, (5) economic projections, (6) education and training, (7) environment, (8) finance, (9) globalisation, (10) health, (11) industry and services, (12) international trade and balance of payments, (13) labour, (14) monthly economic indicators, (15) national accounts, (16) prices and purchasing power parities, (17) productivity, (18) public sector, taxation and market regulation, (19) regions and cities, (20) science, technology and patents, (21) social protection and well-being and (21) transport. From these different categories those indicators are selected which are relevant for demographic passenger information.

Type of data	Category	Coverage and forecast	Description
Migration	Demography and Population	1980-2013	Accounts of foreign population (inflows, outflows, stock, by country).
Population	Demography and Population	1950-2050	Population age groups (by country).
Economic indicators	Economic Projections	2002-2016	Data on different indicators including expenditure and GDP, labour markets (by country).
Labour market	Labour		Employment by economic activities (industry, services, agriculture; by country).

3.1.5 Reports and studies addressing demographic factors
The next table lists various other useful sources of demographic information.

Type of data	Coverage and forecast	Description	Availability	Reference

Type of data	Coverage and forecast	Description	Availability	Reference
Emerging middle class in developing countries	≈2000-2030	Description of global middle class using household survey data and growth projections.	Free of charge	Kharas (2010)
Economic development	2015-2050	GDP projections for different world regions and resulting implications for business strategy.	Free of charge	PWC (2015)
Economic development in Europe	2011-2050	Report presents and quantifies three scenarios that identify the main pathways Europe could follow in the coming decades.	Free of charge	European Commission (2012)
Trade, business and society with a particular focus on the logistics industry	2012-2050	Analysis of trade and consumption patterns, technological and social trends as well as climate change, and their probable impact on people's behaviour and values in 2050.	Free of charge	Deutsche Post AG (2012)
Economic development, production, sustainability	2012-2052	Book that addresses different topics and their potential future development.	Costs apply	Randers (2012)
Aviation and emissions	2010-2050	Scenarios on aviation and emissions that address the key aspects of interest to stakeholders, specifically the aviation industry, policy makers, climatologists and transport researchers.	Free of charge	CONSAVE (2005)
Transport and mobility	2011-2050	Potential developments in transport fuels, technologies and mobility systems over four decades.	Free of charge	World Energy Council (2012)
Economic development	2012-2050	Long run growth scenarios for 147 countries based on a three-factor production function of labour, capital and energy.	Free of charge	Fouré *et al*. (2012)
Aviation and emissions	2010-2050	Methodology and results for calculating future global aviation emissions of carbon dioxide and oxides of nitrogen from air traffic.	Journal access cost	Owen *et al*. (2010)
Aviation and tourism	2012-2050	Analysis of climate change impacts on long-haul tourism, description of three meta-level scenarios.	Free of charge	Vorster *et al*. (2013)

Type of data	Coverage and forecast	Description	Availability	Reference
Transport and travel behaviour	2013-2030	Medium and long-term scenarios through modelling, forecasting and analysing factors influencing transport and travel behaviour; alternative visions to promote co-modality through more or less strict market regulations, at national and European level, by applying alternative planning and public investment strategies, and public-private partnerships.	Free of charge	ORIGAMI (2013)
European mobility development	2011-2050	Scenario and modelling analysis in order to formulate distinct scenarios addressing future passenger and freight demand.	Free of charge	TOSCA (2011)
Energy demand	2008-2015	Development and analysis of scenarios with a particular focus on energy-related aspects such as supply and demand, and the efficient use of available resources.	Free of charge	Shell International BV (2008)
European air traffic development	2013-2035	Development and analysis of different scenarios considering the development of European air traffic and related system components up to 2035.	Free of charge	EUROCONTROL (2013a)
European air traffic development	2013-2050	Development and analysis of different scenarios considering the development of European air traffic and related system components up to 2050.	Free of charge	EUROCONTROL (2013b)
German mobility development	2015-2035	Analysis and development of scenarios regarding potential futures in Germany with a particular focus on the development of mobility.	Free of charge	Phleps *et al*. (2015)
Personalised mobility	2013-2050	Development and analysis of different scenarios and respective implications for future personalised mobility.	Free of charge	TU München (2013)
Megatrends	2020+	Outline and description of different megatrends shaping future developments in different areas.	Free of charge	UP Nord (2015)

3.2 Passenger demand

The data sources outlined in this section relate to passenger demand, i.e. how and when do passengers travel. Information on infrastructure and transport means can provide an approximation of passengers travelling on particular routes.

3.2.1 European Commission

Source:	Eurostat
URL:	http://ec.europa.eu/eurostat/
Availability:	Free of charge

Eurostat (transport statistics): The data comprises information on the following transport modes: rail, road, inland shipping, maritime and air transport. In the following table, data types and data availability are outlined by mode.

Type of data	Coverage and forecast	Description
Railway	1979-2013	Length of tracks (by country).
	2004-2014	Passengers transported annually (by country).
	2002-2014	International railway passengers (arrival and destination country, by country).
Road	1970-2013	Length of motorways (by country).
	1991-2012	Passenger cars per 1000 inhabitants (by country).
	1970-2013	Passenger road transport on national territory, by type of vehicles registered in the reporting country (by country).
Maritime transport	1997-2012	Passengers (all ports, by direction; by country).
Air transport	2001-2013	Number of airports (>15000 passengers per year) (by country).
	2003-2013	Airport connections to other modes of transports (by mode, by airport).
	1993-2015	Air passenger transport data (by country, by main airports, between countries, between main airports).
	1993-2015	National air passenger transport (by country, by main airports).
	1993-2015	International intra-EU air passenger transport (by main airports, by country).
	1993-2015	[International extra-EU air passenger transport (by main airports, by country).]
	1993-2015	Detailed air passenger transport data by main airports of each

Type of data	Coverage and forecast	Description
		reporting country to main partner airports.
	2003-2014	Aircraft traffic (by country, by main airport).
	2003-2014	Airline traffic (by main airport).
	1993-2013	Passenger air transport by NUTS2 regions.

3.2.2 World Bank

Source: World Bank Open Data
URL: http://data.worldbank.org/
Availability: Free of charge

Limited data by transport mode are available from the World Bank.

Type of data	Coverage and forecast	Description
Air transport	1981-2014	Registered carrier departures worldwide (domestic take-offs and take-offs abroad of air carriers registered in the country).
Infrastructure	1981-2012	Rail lines (total route-km).

3.2.3 Data on passenger transport demand
The next table lists various other useful sources of passenger demand information, both qualitative and quantitative.

Type of data/trends	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Airport connectivity	✓	✓	2004-2014	Analysis of different dimensions of airport connectivity using the Netscan model: direct, indirect, hub, and onward connectivity; outline of the development of the connectivity to different global regions.	Free of charge	ACI EUROPE (2014)
Passenger air transport demand	✓	✓	2014-2034	Outline of drivers for air travel demand, including projections until 2034; forecast regarding O&D flows between different countries and within regions.	Free of charge	Pearce (2015)

Type of data/trends	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Passenger air transport demand	✔	✔	2014-2034	Global 20 Year Passenger Forecast projects that passenger numbers are expected to reach 7 billion by 2034 with a 3.8% average annual growth in demand (2014 baseline year); Europe is forecast to have the slowest growth rate of the global regions (2.7%), but will still have an additional 591 million passengers a year; total European market will be 1.4 billion passengers in 2034; free summary available in a Press Release.	Report access cost	IATA (2015b)
Passenger air transport demand	✔	✔	Current (up to 2015)	Monthly analysis of air passenger traffic figures, differentiation between economy and business class passengers.	Free of charge	IATA (2015a)
Passenger air transport demand		✔	2005/2010	Model of passenger (and freight) flows for rail, air, road (private/public) modes; 2005 and 2010 references years.	Free of charge (regist-...)	ETISplus (2015)
Value of connecting times	✔	✔	2006	Analysis of passenger utilities from short vs. long connecting times in order to assess value gained for airlines vs. disutilities during airport peak times.	Journal access cost	Theis et al. (2006)
Air-rail services	✔	✔	2013	Analysis of passengers' willingness-to-pay in regard to air-rail intermodal services using different choice variables such as price, check-in/luggage withdrawal, guarantee in the case of delay, connecting time, and services in the train.	Journal access cost	Chiambaretto et al. (2013)
Airport access	✔	✔	2014	Analysis of how improvements in airport surface access influence consumer airport choice.	Journal access cost	Johnson et al. (2014)

Type of data/trends	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Airport connectivity	✓	✓	2013	Country-level analysis of airport connectivity including different transport modes and their level of interconnectedness with the respective airport.	Free of charge	ModAir (2013)
Transport demand	✓	✓	2012-2050	Mobility projections passenger-km, modal composition in OECD countries as well as vehicle stock.	Free of charge	International Transport Forum
Air transport demand and supply		✓	2013-2050	Forecast regarding air transport development in Europe including traffic movements and available capacities.	Free of charge	EUROCONTROL (2013b)
Air traffic demand	✓	✓	2015-2034	Forecast regarding demand for air travel (by region) considering different factors: economy, development of city-pair connections, developing regions, network and traffic forecast.	Free of charge	Airbus (2015)
Air traffic demand	✓	✓	2015-2034	Forecast regarding demand for air travel (by region) projecting air traffic growth, market size and required aircraft fleet.	Free of charge	Boeing (2015)
Air traffic demand	✓	✓	2012-2031	Data containing information of ≈200 world airports, illustrating demand for air travel and respective forecasts, including a regional differentiation.	Subscription cost	ACI (2013)
Air traffic demand		✓	2012-2035	2013 update of EUROCONTROL's 20-year forecast of IFR flight movements in Europe up to 2035; focuses on developments after 2019 (as 2012-2019 is covered by their 7-year forecast); four scenarios: global growth, regulated growth (most-likely), happy localism and fragmenting world; the most-likely scenario has 14.4 million flights in 2035 (50% more than 2012, i.e. 1.8% average annual growth); annual forecast traffic.	Free of charge	EUROCONTROL (2013a)

Type of data/trends	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Air traffic demand		✓	2015-2021	Access to STATFOR traffic statistics and 7-year forecast; annual forecast traffic between countries/regions available.	Free of charge (regist-ration)	EUROCONTROL (2015b)
Air traffic demand		✓	2005/2020/ 2030	The TRANS-TOOLS project (2004-2006) developed a GIS-based European transport network model covering passenger journeys by car, rail and air transport; baseline 2005 with forecasts for 2020 and 2030.	Free of charge (registration required)	TRANS-TOOLS (2015)
Future trends regarding air traffic demand	✓	✓	2010-2020	Analysis of current and future trends airlines and travel agencies will face, macroeconomic forecasts regarding the travel industry in 2020, outline of new revenue sources for airlines and travel agencies.	Free of charge	Amadeus (2010)
Airport connectivity Air transport demand	✓	✓	2014	Analysis of air connectivity, drivers and implications for air transport demand; air transport demand in emerging economies and resulting implications for airport investment.	Free of charge	PWC (2014)
German transport market	✓		2014/2015	Data on rail, maritime, road and air transport: infrastructure, km-travelled, traffic flows, persons transported.	Free of charge	Bundesministerium für Verkehr
Air transport data	✓		Current	Annual, monthly, weekly statistics on RPKs, ASKs, load factors and passenger numbers across member airlines.	Free of charge	Association of European Airlines
Passenger requirements	✓	✓	Current	Airline and airport reviews considering different criteria such as service, comfort and passenger expectations.	Costs may apply	Skytrax (2015)

Type of data/trends	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Passenger requirements	✓	✓	2014 and outlook	Findings from a survey of airline executives and air passengers; passengers have issues with every segment of the experience: booking flights, getting to/from the airport, traversing the airport, the flight; spending less time in the airport was the most popular passenger improvement (78%); top passenger priority when booking flights was for integrated booking and schedule information across the travel industry, including intermodal (31%); top passenger priority for improving boarding and in-flight experience was for electronic data exchange (58%); other improvements are discussed.	Free of charge	Sabre Airline Solutions (2014)
Multimodal		✓	2014	Survey findings show that use of multimodal transport is increasing; 9% of respondents had used a single ticket combining different modes of transport in the last 12 months (breakdown by country).	Free of charge	European Commission (2014)
Airport connectivity	✓	✓	2015	Analysis of airports in terms of connectivity, i.e. inbound and outbound traffic during a particular day.	Free of charge	OAG (2015a)
Air traffic demand (London airports)	✓	✓	up to 2030	Analysis of traffic situation at London's airports and discussion of different scenarios.	Free of charge	International Transport Forum

3.2.4 Future strategies of different transport modes

Key future goals of European transport strategies by sector.

Transport sector	Main goals	Reference
Aviation	1. European citizens are able to make informed mobility choices and have affordable access to one another, taking into account: economy, speed, and tailored level of service. Travellers can use continuous, secure and robust high-speed communications for	European Commission (2011a)

Transport sector	Main goals	Reference
	added-value applications. 2. 90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours. Passengers and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on-time. 3. Flights arrive within one minute of the planned arrival time regardless of weather conditions. The transport system is resilient against disruptive events and is capable of automatically and dynamically reconfiguring the journey within the network to meet the needs of the traveller if disruption occurs. Special mission flights can be completed in the majority of weather, atmospheric conditions and operational environments. 4. An air traffic management system is in place that provides a range of services to handle at least 25 million flights a year of all types of vehicles, (fixed-wing, rotorcraft) and systems (manned, unmanned, autonomous) that are integrated into and interoperable with the overall air transport system with 24-hour efficient operation of airports. 5. A coherent ground infrastructure is developed including: airports, vertiports and heliports with the relevant servicing and connecting facilities, also to other modes.	
Railway	1. Dealing with rapid urbanisation and population growth: linking major urban hubs and creating multi-modal local transport systems. Rail service should be able to cross borders without delays or technical barriers, providing a competitive option to air or road travel, particularly for interurban journeys and commuting into large urban areas. 2. Technological progress will be one of the major drivers of change for the railway sector: Advances in nanotechnology in particular will lead to lighter, stronger, smarter and greener materials. Intelligent robots and drones play a greater role in the inspection of infrastructure such as tunnels and bridges. Due to automated passenger trains designed for speed and operational safety rail will be more competitive and will be less reliant on government subsidies. Ticketless technology will remove gate-lines in stations and payment processed automatically when the journey is taken. Integrated journey apps will provide a seamless journey planning tool, which makes it possible to book and pay for journeys across all modes. Freight pipelines will transport goods and luggage safely and rapidly with low maintenance needs and costs. Smart and integrated mobility will provide accurate real-time information and optimal pricing. 3. Energy and resources: There will be a shift towards alternative	Arup (2015)

Transport sector	Main goals	Reference
	forms of fuel lowering transportation costs significantly and transforming the global economy. By 2050 there will be a better application of a circular economy – where used materials are recycled back into the production stream, reducing waste and increasing efficiency. 4. Stations will become destinations and lifestyle centres that further blend our commute with our lives. People are increasingly using stations, not just as places to catch a train, but as centres for leisure and business. Station office suites and virtual shopping walls are examples to fulfil the passengers' needs besides travelling.	
Railway	Shift2Rail Joint Undertaking (S2R JU) is a new public-private partnership in the rail sector, providing a platform for cooperation to drive innovation (within the Horizon 2020 programme); S2R JU will pursue research and innovation activities in support of the achievement of the Single European Railway Area and improve the attractiveness and competitiveness of the European rail system; five key "Innovation Programmes": 1. cost-efficient and reliable trains, including High Speed trains and high-capacity trains; 2. advanced traffic management & control systems; 3. cost-efficient and reliable high capacity infrastructure; 4. IT Solutions for Attractive Railway Services; 5. Technologies for Sustainable & Attractive European Freight.	Shift2Rail Joint Undertaking (2015)
Road Transport / Automotive industry / Bus transportation	1. A road network that provides a more reliable and freer-flowing system for motorists, other road users and businesses, where travellers can make informed choices about how and when they travel, and so minimise the adverse impact of road traffic on the environment and other people. Due to intelligent traffic surveillance and investments in the road network street safety will be further improved and congestion management will have a greater performance. 2. Improved network management allows smarter choices in travel plans and helps to consider alternatives to using the car as a mean of transportation especially for travelling at peak hours. 3. Further advances can modernise the programme for registration and services for road users and ensures new ways of paying for road use. 4. Technological advance in the automotive industry can encourage the development and introduction of new fuels due to	Department for Transport (2004)

Transport sector	Main goals	Reference
	a rise in prices for fossil fuel and highly developed vehicles to ensure energy efficiency and the reduction of emissions. 5. The bus network will provide a quick, flexible and seamless way of transportation as this is crucial for people with no access to car or motorbike. Travelling by bus will help reduce congestion and will provide a frequent, reliable and environmentally friendly way of transportation. Coaches will make an important contribution to travel between smaller suburban regions and cities as well as improve connectivity within large cities.	
Maritime Transport	1. As the passenger market for maritime transport is declining the focus of development will be in efficient freight transportation as economic growth will increase the demand for goods and therefore the need for fast and reliable transportation. 2. A sustainable strategy on the development of major container ports will be defined in order to deal with forecasts of global growth in shipping traffic and the role of the government in the port sector will be clarified. 3. Although shipping is considered to be a sustainable and environmentally friendly form of transport, it is important that efforts are made to reduce negative impacts on the environment and improve technical standards to encourage growth and minimise pollution.	Department for Transport (2004)
All transport modes (distinction by medium and long distances as well as urban transport)	1. Single European transport area: a. Further consolidation and expansion of trans-European transport network; convergence of rules and regulations; implementation of Single European Sky, single European railway area, facilitating and improving maritime transport; b. Alignment of job quality and social agenda; c. Cooperation in the field of transport security and safety (e.g. civil aviation safety strategy, SafeSeanet), harmonisation of safety certification in rail transportation; d. Seamless door-to-door mobility (quality, accessibility, reliability), optimisation of intermodal chains; e. Harmonisation of passenger rights. 2. Innovation: a. Introduction and implementation of new technologies for vehicles and traffic management to reduce emissions; investment decisions and implementation of respective strategic research agenda; b. Smart mobility systems (SESAR, ERTMS, SafeSeaNet, RIS, ITS), interoperability and interconnectedness, vehicle propulsion and alternative fuels; c. Establishment of regulatory framework, standardisation and interoperability requirements; d. Promoting and incentivising sustainable mobility behaviour,	European Commission (2011b)

Transport sector	Main goals	Reference
	seamless intermodality; e. Reducing urban congestion and emissions. Reduction of greenhouse gas (GHG) emissions by transport sector by 60% by 2050 (compared to 1990 levels); by 2030 reduction of around 20% below 2008 level. 3. Infrastructure, pricing and funding: a. Establishment of core network corridors for high-density and efficient transport flows; efficient multimodal combinations; b. Alignment of eastern and western European infrastructure standards; c. Widespread application of information technology tools; d. Improvement and establishment of multimodal links and multimodal terminals; e. Internalisation of externalities, elimination of tax distortions and unjustified subsidies; f. Charging structure for different transport modes to foster sustainable behaviour; g. Greater consistency across different transport modes, i.e. create level playing field.	

3.3 Passenger type

3.3.1 Data on passenger profiles

Within this section, different passenger types are outlined in a qualitative way. Today, passengers are mainly structured according to their travel purpose, i.e. business, leisure, or visiting friends and relatives (VFR). The studies below go beyond the traditional definition of passengers and aim at establishing passenger groups according to other metrics than the classical ones. In the course of the project, these passenger profiles from different studies are analysed in regard to overlaps and underlying factors.

Each type will be categorised according to travel purpose, length of stay, income, age group and other criteria yet to be defined. The goal is to define qualitative profiles with the datasets obtained and thus establish a quantitative foundation for each passenger demand profile.

Passenger group/ cluster	Description	Reference
Screenagers	Teenagers that grew up with connectivity and pervasive use of technological devices/applications and hence expect ubiquitous, fast and reliable connectivity.	SITA (2015a)
Bleisure passenger	Passengers combining business trips with leisure activities (sightseeing, dining, art/culture), bringing along family members, adding extra days to business trip.	Skift (2015)

Passenger group/ cluster	Description	Reference
Millennials	Passengers that grew up with using technology in all areas of life, mobile devices are used to control travel and "on-the-go" booking etc; blur between leisure and work, sharing economy, "pay for what you use" mentality.	OAG (2014)
Simplicity searcher	Outsourcing of decision-making to third parties and systems, simplified choices bundled into packages; travel: safe and comfortable and have a "home-away-from-home" feeling; new travellers from emerging markets including first-time tourists fall into this category.	Future Foundation (2015)
Cultural plurists	Seeking to experience true local lifestyle, avoiding common tourist destinations, "niche experience"; not using traditional travel agencies but rather networks to connect and exchange with other travellers alike; travelling to remote, non-tourist destinations; sharing as part of the travel experience; travel purpose in line with personal interests.	Future Foundation (2015)
Social capital seekers	Expected personalisation according to individual preferences and interests; sharing of holiday experience online (often in real time); decision-making strongly based on social opinion and trends; social media presence of both travellers and suppliers (e.g. travel brands) is expected; travellers seek rewards for their social interaction and sharing, e.g. rewards by travel brands; ubiquitous, free connectivity with sufficient bandwidth is expected; travellers want to increase personal (online) recognition.	Future Foundation (2015)
Reward hunters	Seeking (travel) rewards for high achievements in business/personal life; demand for temporary escape, focus on indulgence, minimising personal effort, unique experience; technology used as a means to obtain unique travel experience but otherwise rather avoided; quantified self: online health tracking and biometric data sharing.	Future Foundation (2015)
Obligation meeters	Travellers with strict travel specifications; teleconferencing as supplement for business travel; hassle-free, minimal-choice booking, integrated platforms, covering entire journey; simplification of travel-related processes and real-time information along the journey; integrated airport and airline systems required to enable flexible journey management (alignment in case of disruptions); efficient conversion of waiting time into productive time; ensuring network security and continuous connectivity; loyalty programs and tracking of passenger preferences.	Future Foundation (2015)

Passenger group/ cluster	Description	Reference
Ethical travellers	Increasing ethical awareness (environmental, social, political conditions and effects of travel), adjustment of travel behaviour accordingly; increased pressure on corporate social responsibility; increased transparency regarding (carbon) footprint of entire journey, widespread carbon offsetting and automated carbon footprint tracking along the journey; online sharing and exchange of recommendations for ethically-friendly travel options.	Future Foundation (2015)
Young urban hopper	Travel during off-season months, budget travelling (hostels, friends and family, "couch surfing"); spontaneous booking behaviour, focused on online offers; young travellers (students, young professionals) but also "young at heart"; fun and action as main motivation; city trips.	GfK Mobilitätsmonitor (2011)
Leisure and family tourist	Family focused, usually travelling for two weeks; package tours with tour operators; destinations in the Mediterranean; aged between 30 and 44, middle income class; relaxation as main focus.	GfK Mobilitätsmonitor (2011)
Mediterranean best-ager	Package tours, spending higher than average; main travel period during off-season; selection of 4-/5-star hotels; traditional ways of information acquisition; dominated by persons >60 years; belonging to middle income class; seeking relaxation (wellness, creativity).	GfK Mobilitätsmonitor (2011)
Culture and knowledge seeker	Long-distance travel, mainly during winter months; travel usually involves air transport; contacting different information sources, booking with tour operator; city and cultural destinations; tertiary education, top end of middle class/high income group; exploring new cultures and sites.	GfK Mobilitätsmonitor (2011)
Silver traveller	Culture and sightseeing; large travel budget and longer trips (>14 days), travel during off-season; use of small and specialised tour operators, close contact and exchange with operators; dominated by travellers >60 years.	GfK Mobilitätsmonitor (2011)

3.3.2 Data on passenger behaviour and expectations along the journey

Studies and data sources are outlined below that address different passenger behaviour and expectations along the journey. Here, different trends such as digitalisation or perception regarding privacy issues are collected. These serve as a basis to formulate different passenger profiles including passenger requirements concerning the availability of information along the journey, airline in-flight services or airport products.

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Passenger en-route require-ments	✓	✓	2015	Survey regarding passenger perception in regard to technological advancements in the airline and airport industry and respective products and services.	Free of charge	SITA (2015b)
Digital-isation	✓		2013	Outline of passenger activities prior to boarding (by passenger type); outline of qualitative airport goals to provide seamless travel for passengers; outline of projects regarding the realisation of seamless travel at Munich airport.	Free of charge	Zaddach (2014)
Passenger expect-ations	✓		2014 and future outlook	Discussion regarding "who owns the passenger experience – airports or airlines?"	Free of charge	Brentini (2014)
Self-services	✓		2014 and future outlook	Technologies as enabler for tailored passenger journeys (outline of devices, products and services offered to passengers), examples of implementation approaches at Montreal Airport, smartphones as key tool, passengers controlling their own journey.	Free of charge	Cherry (2015)
Passenger flow manage-ment Self-services	✓		2014 and future outlook	Passenger flow tracking (information for both airport operator and passengers), identification of bottlenecks.	Free of charge	Koski (2015)

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Self-services	✓		2014 and future outlook	Outline of self-service examples from different areas at the airport: passenger immigration and customs, baggage handling, security processes, services and products (e.g. tag bags), future outlook: smart security, airport configuration, integrated solutions.	Free of charge	Rostworowski (2014)
Passenger en-route require-ments Airline trends Airport trends	✓		2015	Overview of developments in the airline and airport market in terms of technological advancements, products and services offered to passengers.	Free of charge	airlinetrends.com (2015)
Self-services	✓		2015 and future outlook	Outline of benefits for different stakeholders (airlines, airports, passengers) and options for implementation.	Free of charge	Costain (2015)
Self-services Digital-isation	✓	✓	2014 and future outlook	Presentation of SITA IT Survey 2014: airport IT spending, airport priorities, new airport service initiatives and planned implementations (services, products), services for the connected traveller, smarter airports.	Free of charge	Verschuren (2014)
Digital-isation In-flight services	✓	✓	2015 and future outlook	Outlook on passenger engagement along the journey; outlook towards airline and airport undertakings in regard to shaping the future passenger journey.	Free of charge	SITA (2015a)
Passenger expect-ations	✓	✓	2015 and outlook	Discussion regarding the evolution of passengers requirements as well as technological advancement in terms of airline and airport processes, offered products and services.	Free of charge	IATA (2015c)

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Airport check-in	✓	✓	1999	Development of simulation tool to assess resource requirements in regard to airport check-in counters; integration of different check-in devices, passenger arrival times and rates, and varying service levels.	Journal access cost	Chun and Mak (1999)
Airport check-in Passenger arrival at airport	✓	✓	2003	Development of assignment model to assess efficiency of airport check-in operations using passenger surveys on arrival patterns and distribution (case study Seoul Gimpo Airport).	Journal access cost	Park and Ahn (2003)
Airline business models	✓	✓	2004-2012	Analysis of the evolution of airline business models using a set of 26 European airlines; The empirical consideration of 36 different parameters shows a stronger convergence of existing models.	Conference proceedings (charges may apply)	Daft and Albers (2013)
Airline business models	✓	✓	2015	Cluster analysis to identify and categorise different airline business models according to pre-selected criteria.	Unpublished master thesis	Klemm (2015)
Passenger types	✓	✓	2006	Analysis of different passenger types in regard to motivation to fly, parking requirements and amount of luggage checked-in.	Journal access cost	Dresner (2006)
Passenger buying behaviour	✓	✓	2005	Theoretical analysis of the relationship between time spent at the airport and amount spent in non-aviation businesses, empirical application to Asturias Airport (Spain).	Journal access cost	Torres *et al*. (2005)

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Passenger scheduling behaviour		✓	2014	Modelled expected user costs of US domestic air travel delay variability taking into account scheduling behaviour of passengers; note that if a connection arrives close to the passenger's preferred arrival time, the probability that the passenger will choose this connection will be higher.	Journal access cost	Koster *et al*. (2014)
Passenger itinerary		✓	2014	2014 passenger itineraries are being developed by UoW for the SESAR WP-E ComplexityCosts project (building on an existing in-house 2010 dataset); each itinerary assigns a passenger to individual flights, with up to two connections, along with ticket price and premium/non-premium seat class distinction.	Free of charge	University of Westminster in-house dataset
Passenger loyalty prog-rammes	✓		2007	Theoretical analysis of the effects of loyalty programmes.	Journal access cost	Caminal and Claici (2007)
Airport service quality	✓		2007	Literature review and passenger survey regarding passenger perception of airport service quality to measure passenger expectations in this area.	Journal access cost	Fodness and Murray (2005)
Airport service quality	✓	✓	2009	Analysis of overall service perception of transfer passengers at their connecting airports using regression analysis (example Sri Lanka).	Journal access cost	Barros *et al*. (2007)
Airport service quality	✓		2007-2008	Analysis of different passenger travel steps within the airport and according assessment of service quality and potential for improvement.	Free of charge	Civil Aviation Authority (2009)

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Airline customer expect- ations	✓		2050	Qualitative description of the potential customer of the future addressing aspects such as price, safety and security, value of time, or required services along the (air) travel chain.	Free of charge	IATA (2012)
Check-in processes Baggage handling Airport experience Digital- isation, personal devices	✓		up to 2025	Analysis of current airport and airline processes and outline of innovation potential for related processes.	Free of charge	Amadeus (2012)
Passenger types Passenger flows	✓	✓	2010	Overview of passenger arrival times before departure as well as overview of composition of different passenger groups (business, leisure, originating, transfer).	Free of charge	Munich Airport (2010)
Passenger expect- ations	✓		2011	Outline of user needs for long-distance intermodal journeys at a generic level using different user need categories: network characteristics, interchange facilities, baggage handling facilities, door-to-door information, cost, comfort, safety, personal security, journey time, accessibility, promotion of intermodality, employees, effort, in-vehicle facilities, environmental concerns.	Free of charge	ORIGAMI (2011a)
System require- ments	✓		2011	Outline of system needs by transport mode: road, coach/bus, rail, cycling/walking.	Free of charge	ORIGAMI (2011b)

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Passenger en-route require-ments	✓		2013	Overview of passenger requirements in regard to intermodal travel: information, ticketing, luggage, safety and security, comfort, accessibility and reliability.	Free of charge	Whalley and Lorenzo (2013)
Passenger value of time Passenger types	✓	✓	2013	Data on passenger value of time by travel purpose and distinguished by travel time and waiting time; data on passenger travel, purpose and distribution.	Free of charge	EUROCONTROL (2013c)
Passenger expect-ations	✓	✓	2015	Passenger survey on passenger behaviour and expectations in different areas along the (air) transport chain: airline brand perception, comfort, etc.	Free of charge	IATA (2015d)
User require-ments	✓		2007	Outline of expectations and requirements in regard to intermodal transport from different perspectives: passengers, providers, politics; key issues addressed include legal aspects, technical issues, baggage handling, safety and security, market demand, etc.	Free of charge	KITE (2007)
Consumer behaviour (sustainable consumpt-ion)	✓		2015	Analysis of ecological and economic implications of sustainable consumption in society.	Free of charge	Umweltbundes-amt (2015)
Airport and airline products	✓		2015	Overview of already existing passenger-centric solutions at airports and within airlines; survey regarding airline and airport perception.	Free of charge	Roland Berger (2015)

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Travel disruption Passengers with reduced mobility		✓	2014	Survey findings include experience of travel disruption by mode per country; 30% of (all) passengers were affected in the last 12 months, 12% of these were flying rising to 22% among air transport users; 57% not satisfied with the general information received during disruptions. Survey findings reveal 7% of all passengers requested assistance for themselves or another person; 3% of air passengers requested assistance (reduced mobility breakdown by country).	Free of charge	European Commission (2014)
Passenger en-route require-ments	✓		2015-2030	Analysis of passenger consumption patterns based on the previously established traveller tribes outlined above.	Free of charge	Frost & Sullivan (2015)
Passenger en-route require-ments	✓	✓	2015 and outlook	Overview of different challenges for airlines resulting from changing customer requirements, outline of potential business opportunities for airlines.	Free of charge	Sabre Airline Solutions (2015b)
Passenger en-route require-ments	✓		2015 and outlook	Analysis of personalised customer experience and potential implications for airlines (e.g. data-driven personalisation).	Free of charge	Sabre Airline Solutions (2015a)
Passenger ICT require-ments	✓	✓	2015	Analysis of the state of networked readiness of a range of different countries, i.e. overview of the regulatory and business environment, ICT infrastructure, ICT impact on society and business.	Free of charge	World Economic Forum (2015)

3.4 Door-to-kerb

This section summarises information sources required for the door-to-kerb and kerb-to-door phases of passenger journeys. Primarily these cover modal share getting to/from airports and their catchment areas. Note: published data are readily available in the UK, including estimation examples.

Type of data	Coverage and forecast	Description	Availability	Reference
Modal share	2012-2017	Edinburgh Airport's surface access five year plan; aim to increase public transport mode share of departing passengers from 30.9% (2012) to 35% by 2017 (UK).	Free of charge	Edinburgh Airport (2012)
Modal share	2014-2019	Heathrow Airport's surface access five year plan; aim to maintain passenger public transport mode share above 40% (UK).	Free of charge	Heathrow Airport (2014)
Modal share	2012-2030	Gatwick Airport's surface access strategy; includes a vision of how passengers might access the airport in 2030; 65% of public transport users (estimated) arrive by air at Gatwick without tickets for their onward journey, creating inefficiencies in the use of space, queues and longer journey times – airport needs to work with airlines and surface transport providers to increase number of pre-purchased tickets; existing target of 40% of passengers using public transport by the time airport reaches 40 mppa, however aiming for a "stretch target" of 45% once 40% achieved; target to increase public transport share on key surface transport corridors (e.g. Central London from 82.1% (2011) to 90% when 40 mppa reached); summary of annual modal share and modal share by surface transport corridor to 2011 (UK).	Free of charge	Gatwick Airport (2012)
Modal share	2008-2015	Review of Stansted Airport's surface access strategy; by 2009, public transport use had increased to 47.2% of air passengers (note: CAA survey 2013 reports a 51.5% public transport share by 2013); airport is already exceeding its target of 43% of air passengers using public transport by 2014 (assuming 35 mppa); large increase in bus/coach surface access usage; breakdown by "final mode" available (UK).	Free of charge	Stansted Airport (2010)
Modal share	2015-2020	Birmingham Airport's surface access five year plan; passenger modal share targets 2016/2020 by mode (UK).	Free of charge	Birmingham Airport (2015)

Type of data	Coverage and forecast	Description	Availability	Reference
Modal share	2012-2017	London Luton Airport's surface access five year plan; aim to increase public transport mode share of departing/arriving passengers to more than 40% by 2017; mode share by catchment area (UK).	Free of charge	London Luton Airport (2012)
Modal share	2015-2016	East Midlands Airport's annual surface access plan; continued target of 10% of passengers to use public transport (UK).	Free of charge	East Midlands Airport (2015)
Modal share	2015-2016/2033	Manchester Airport's annual surface access plan; only 42% of passenger catchment is from Greater Manchester/Cheshire; need for long-term planning to facilitate local growth potential around Manchester's proposed HS2 and HS3 stations; modal share targets tied with passenger growth, e.g. increasing rail share from 14% (2015) to 18% (30 mppa) and 25% (45 mppa), though around 50% of passenger journeys would still rely on a car when 45 mppa is reached (UK).	Free of charge	Manchester Airport (2015)
Modal share	2008	Information/best practice about the current status of public transportation services at large airports from around the world ; useful comparisons with European airports (and case studies); rail market share by time/distance to CBD; integrated ticketing/baggage strategies; ground access passenger information (USA).	Free of charge	Transportation Research Board (2008)
Modal share	2014-2030/2050	Highlights importance of the "last mile" (to or from the airport) in terms of design, customer experience, and the potential for innovative technology; particularly concerned with the development of Heathrow/Gatwick; recommends technological solutions; hub airports have different surface access requirements to non-hub airports (larger proportion of passengers transferring between flights); importance of ticketing improvements for seamless travel particularly for travellers in a foreign country (UK).	Free of charge	Ryley and Zanni (2014)

Type of data	Coverage and forecast	Description	Availability	Reference
Modal share	2008	Overview of landside access at major European airports (notes that airport access modal share at the European level is unavailable); car remains the most important access mode at most European airports; rail accessibility at the 30 largest European airports; comparison of time/distance to CBD; case studies focus on Amsterdam Schiphol, Barcelona El Prat and Frankfurt Hahn (Germany).	Free of charge	Deutsches Zentrum für Luft- und Raumfahrt e.V. (2010)
Modal share	2014-2030	Compares future access scenarios between Heathrow, Gatwick and a proposed new airport (UK).	Free of charge	Atkins (2014)
Modal choice	2005	Lessons from a modelling model choice of air passengers in the New York/New Jersey metropolitan region (USA).	Free of charge	Kisia *et al*. (2014)
Modal share / catchment area	2010-2014	Summary findings from annual passenger survey at UK airports; since 2010, survey covers the same seven main airports plus other selected airports (20 airports covered 2010-2014); tailored datasets can be purchased. Findings include terminating/connecting passenger share; passenger origin/destination region; private/public transport share (by passenger type/origin); number of modes used; trip length/purpose; passenger income/socio-economic group (UK).	Free of charge	Civil Aviation Authority (2011a; 2012; 2013; 2014; 2015)
Catchment area	2004	Low-cost air travel makes passengers (particularly leisure) more willing to compromise a longer surface access journey to more distant airports in return for lower air fares; small airports do not have the passenger volume required to support fixed rail links (UK).	Free of charge	Dennis (2004)
Catchment area	2004	Air connectivity report for Gatwick Airport with geographic catchment areas for five London's airports (2-hour, 3-hour and 4-hour driving range); catchment areas estimated using MapPoint based on 2004 population data (UK).	Free of charge	InterVISTAS Consulting (2013)

Type of data	Coverage and forecast	Description	Availability	Reference
Catchment area	2011	Informative paper that discusses catchment area analysis – a method of estimating the geographic area from which a large proportion of an airport's passengers originate or travel to, and their geographic distribution within this area; analysis possible using surface access travel time and actual usage data; surface access travel time tends to be a major consideration in passengers' choice of airport, but one that passengers/airlines/airports can influence directly in the short to medium term; the time taken to travel to an airport has been commonly used to define its catchment area; CAA has previously used 120 minutes to construct the drive time isochrone for UK short haul leisure passengers and 60 minutes for UK international short haul business passengers – previously used MapPoint, isochrones now constructed using Department for Transport's airport surface access dataset which contains both road and rail travel time estimates from the centre of each district in England and Wales; surface travel time estimate is given as the lowest value of the rail and road travel times; isochrone maps for four London airports (60/90/120 minute bands); graph plots overall surface access time by percentage of passengers (e.g. 80% of Stansted and Luton passengers' surface travel time is approximately 90 minutes); other graphs show surface travel time by journey purpose, length of flight and for UK/foreign residents (UK).	Free of charge	Civil Aviation Authority (2011b)
Catchment area	2015	Estimated population by catchment area time band; the number of catchment bands vary between airports, but include 30, 45, 60, 90, 120, 180 minutes; 60 minutes catchment band used consistently across airports, with exceptions (e.g. island airports); no explanation of the method used to calculate population within catchment bands (Global).	Free of charge	anna.aero (2015)

Type of data	Coverage and forecast	Description	Availability	Reference
Overview	2010	Airport management perspective on airport surface access based on interviews with personnel responsible at 14 UK airports; paper identifies key issue as the need to reduce modal share made by private car with a particular focus on reducing "kiss-and-fly" journeys for passengers; conflicting airport strategies, as increasing public transport modal share is at odds with the commercial necessities of maximising car parking revenue (a major source of non-aeronautical income – in some cases helping to subsidise public transport services to the airport); observations include passengers travelling to "sun" and "beach" destinations or carrying heavy luggage are especially likely to access the airport by car whilst business passengers are more likely to use public transport as they are typically without heavy luggage; business travellers are more likely to regularly travel hence are familiar with the local public transport network; third party owned/unlicensed off-site parking facilities are fairly common at UK airports and are typically located some distance away from the airport; involvement of surface access stakeholders (Highways Agency/local authorities, train operating companies, Network Rail/infrastructure companies, bus/coach companies); larger airports may have the financial resources to subsidise unprofitable public transport services; kiss-and-fly generate four trips to the airport rather than two had the passenger driven themselves and parked – activity can be discouraged by charging to drop-off; now common for LCCs to sell public transport tickets on board/on-line, thereby influencing passenger behaviour (UK).	Journal access cost	Thomas *et al.* (2011)

3.5 Kerb-to-gate

Although both the kerb-to-gate and gate-to-kerb phases cover the movement of passengers between the airport entrance or exit (i.e "kerb") and airport gate, their associated processes differ. For example, kerb-to-gate includes check-in, security screening and airport dwell time, whilst gate-to-kerb includes immigration checks, baggage reclaim and customs. Data availability for these phases are limited.

3.5.1 Kerb-to-gate data

This section covers processes that begin on entry to the airport. Note: the minimum connecting times of connecting passengers are included here.

Type of data	Coverage and forecast	Description	Availability	Reference
Check-in time profile	2011	Check-in time profile for the peak summer week in 2011 at London Luton Airport; time profile of passengers requiring inbound surface access; no passenger numbers (due to commercial confidentiality) however distribution by hour over seven days; daily peak from 04:00 to 05:00 (Monday-Saturday) with smaller peaks at lunchtime and in the early evening (UK).	Free of charge	London Luton Airport (2012)
Security screening time	2009-2014	Summary results about passenger security screening from Civil Aviation Authority Passenger Survey; Annex B Table C4a has the proportion of passengers per queuing time band (i.e. 0 mins, 1-5 mins, 6-10 mins, etc.) at Heathrow, Gatwick, Stansted, Luton, Manchester, per airport terminal, by passenger characteristics; Annex B Table C4b has proportions per queuing time band for these five airports and selected others from 2009-2014 (UK).	Free of charge	Department for Transport (2014)
Security screening time	2015	Summary of Commission proposals for EU level aviation agreements with key partner countries – once signed, almost 75% of passengers flying in and out of the EU (over 240 million passengers pa) would be covered by EU-level aviation agreements; these include arrangements for One Stop Security with Canada and Montenegro *[which should improve minimum connecting times between flights]*; comprehensive agreements with neighbouring States aim to establish a fully open Common Aviation Area through regulatory convergence with the final goal of full implementation of EU aviation legislation and market access to the EU, including intra-EU routes (EU).	Free of charge	European Commission (2015b)
Dwell time	2014	Dwell time by stage of airport processing (Global).	Report access cost	Moodie International and The S-A-P Group (2014)

Type of data	Coverage and forecast	Description	Availability	Reference
Minimum connecting time	2014	Published airport minimum connecting time data in a usable format (including connection details and minimum connecting time).	Subscription cost	Innovata (2015b)
Minimum connecting time	2014	Published airport minimum connecting time data in a usable format (including connection details and minimum connecting time).	Subscription cost	OAG (2015b)

3.5.2 Gate-to-kerb data

This section covers processes that take place on arrival to exit at the destination airport.

Type of data	Coverage and forecast	Description	Availability	Reference
Exit time profile	2011	Exit time profile for the peak summer week in 2011 at London Luton Airport; time profile of passengers leaving the Airport terminal requiring outbound surface access; no passenger numbers (due to commercial confidentiality) however distribution by hour over seven days; profile is less peaked with small numbers arriving during the early hours (UK).	Free of charge	London Luton Airport (2012)
Immigration queuing time	2007	Gatwick Airport average/maximum immigration queue time per month per terminal for EEA and non-EEA passengers; peaks in queue times in July and September 2008 correspond with peaks in seasonal demand; monthly average immigration queue times for EEA passengers between 2-10 minutes in the North Terminal and 6-16 minutes in the South Terminal (longer for non-EEA passengers) (UK).	Free of charge	Department for Transport (2009)
Immigration queuing time	2011-2015	Gatwick Airport monthly immigration queue performance statistics based on 15 minute time period measurements (UK Border Force); percentage target reached for EEA (queue ≤ 25 minutes) and non-EEA (queue ≤ 45 minutes) passengers per terminal (UK).	Free of charge	Gatwick Airport (2015)
Immigration queuing time	2007	Heathrow and Gatwick airports average/maximum immigration queue time per terminal for EEA and non-EEA passengers over a two-week period in October 2007 (UK).	Free of charge	Department for Transport (2007)

Type of data	Coverage and forecast	Description	Availability	Reference
Immigration queuing time	2012-2015	Heathrow Airport monthly immigration queue performance statistics based on 15 minute time period measurements (UK Border Force); percentage target reached for EEA (queue ≤ 25 minutes) and non-EEA (queue ≤ 45 minutes) passengers per terminal (UK).	Free of charge	Heathrow Airport (2015)

3.6 Airside capacity

The follows sources provide information required for airside system capacity, i.e. schedules, traffic and network.

Type of data	Coverage and forecast	Description	Availability	Reference
Airline schedules	2013	Paper investigates the relationship between scheduled block time and historical block time distribution using empirical data (US) and multiple regression models; found longer scheduled block time is set for larger airports, as padding for busy traffic; legacy carriers set a shorter scheduled block time for flights between their own hubs, to avoid the disruption of early arrivals; low cost carriers tend to set a shorter scheduled block time than legacy carriers.	Free of charge	Hao and Hansen (2013)
Airline schedules	2014	Published airline schedule data in a usable format (including flight number, aircraft type, origin, destination, stopover, departure time, arrival time, day of operation) with codeshare information.	Subscript-ion cost	Innovata (2015a)
Airline schedules	2014	Published airline schedule data in a usable format (including flight number, aircraft type, origin, destination, stopover, departure time, arrival time, day of operation) with codeshare information.	Subscript-ion cost	OAG (2015c)
Flight/route data	2014-2021	EUROCONTROL's Demand Data Repository (DDR2) provides historical flight and environment data in a range of formats; DDR2 also generates forecast flight data from 5-7 years in advance.	Free of charge (regist-ration required)	EUROCONTROL (2015a)

Type of data	Coverage and forecast	Description	Availability	Reference
Route network	2014-2020	EUROCONTROL's European Route Network Improvement Plan Database lists short-term (e.g. next summer), medium-term (<3-5 years) and long-term (>3-5 years) improvement projects planned for implementation or under development to improve the Pan-European ATS route network, airspace structure and optional use of both of them.	Free of charge (registration required)	EUROCONTROL (2015c)
Airport traffic forecast	2012-2031	ACI Global Traffic Forecast 2012-2031. It is based on detailed inputs from approximately 200 airports around the world, from small airports to large hubs.	Subscription cost	ACI (2013)
Airport capacity forecast	2012-2035	Current and forecast declared runway capacities (hourly and yearly). Coverage: traffic at European airports representing ≈70% of all European flights in 2012 (excel table).	Some data confidential	EUROCONTROL (2015d)
En-route capacity forecast	2012-2019	ACC capacity figures, LSSIP – Year 2013 reports provide the estimated capacities until 2019.	Free of charge	EUROCONTROL (2015e)

3.7 Competing services

This section outlines studies and data that investigate the relationship between air transport and competing services such as other transport modes or information and communication technologies.

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Air-rail competition	✔	✔	1999-2009	Analysis of impact of new high-speed rail lines on frequencies offered by airlines as well as changes in airlines' market shares.	Free of charge	Jiménez and Betancor (2011)
Air-rail competition	✔	✔	2002	Game-theoretical approach to analyse the level of competition on an intra- and intermodal level.	Free of charge	IDEI (2005)

Type of data	Qualitative	Quantitative	Coverage and forecast	Description	Availability	Reference
Air-rail competition	✓	✓	2003-2004	Analysis of customer preferences on the London-Paris market considering the choice between air and rail transports, explanatory variables include average fares, frequency, capacity, and speed.	Free of charge	Behrens and Pels (2009)
Air-rail competition	✓	✓	2008	Methodology to analyse intermodal competition and the level of potential substitution (legacy vs. low cost carriers vs. high-speed rail).	Free of charge	Adler *et al*. (2008)
Transport-ICT competition	✓		2014	Analysis of the relationship between the development in the information and communication technology sector and consumer mobility choice, i.e. whether replacement is taking place and how ICT affects scheduling decisions.	Free of charge	Pawlak *et al*. (2015)
Competing technology	✓		2030/2050	In the context of reducing the impact of drop-off/pick-up trips (i.e. door-to-kerb), this report mentions the findings of the ABC project (2009-2012). Among the technologies reviewed, 3D television-based communication (telepresence systems) could play a role in the future with survey findings showing that although 25% of respondents would not make any change to their willingness to be dropped-off/picked-up at airports, about 20% said it could.	Free of charge	Ryley and Zanni (2014)

4. Implications for the model

4.1 Summary of data status

4.1.1 Available data and acquisition

Data availability is generally good for the current scenario (note green shading in Table 4). On the demand-side, there are multiple free data sources that cover most of the expected demographic and passenger demand inputs (Sections 3.1 and 3.2). In particular, data can be sourced from the European Commission (Eurostat), the World Bank, the United Nations (UNdata) and the Organisation for Economic Co-operation and Development. Passenger type profiles are being defined with reference to key industry reports whereas qualitative and quantitative information relating to passenger behaviour are being sourced from various publications (Section 3.3). Although various data inputs are available in-house, one notable key dataset being prepared by UoW is a 2014 passenger itinerary database.

Turning to the supply data groups, much of the available data that covers the door-to-kerb and kerb-to-gate inputs (Sections 3.4 and 3.5) are currently sourced from UK airports, though we anticipate being able to be source additional information from other European airports. Older airport minimum connecting time data are available (in-house), however if it becomes clear that these have significantly changed, 2014 MCTs will need to be purchased. Data are readily available for airside capacity requirements (Section 3.6), with flight, route and capacity data sourced in-house from EUROCONTROL. Limited schedule data are available in-house but extending this coverage with additional data will require purchase.

The final data group, competing services (Section 3.7), has qualitative and quantitative information available for air-rail competition considerations but there is currently limited information for competing technology requirements.

4.1.2 Missing data and solutions

As might be expected, Table 4 shows missing data as a problem that affect the future scenarios. An exception is for demographic-related data, for which forecasts are available (e.g. published by the Organisation for Economic Co-operation and Development). Members of the project consortium have long-standing experience of preparing robust datasets, including imputing missing data (e.g. SESAR WP-E POEM project). In addition to imputing data, in some cases missing data will be modelled using reasoned assumptions and inferences. Resulting solutions will be discussed with industry stakeholders at the first DATASET2050 workshop and through other communication and dissemination channels.

4.2 Integration with modelling

4.2.1 Modelling the Air Transportation system, a data-driven approach

One of the main focuses of the DATASET2050 Coordination and Supporting Action is to assess the current (and future) status of the European mobility, door-to-door itineraries involving any type of air transportation. However, as described in Section 2, there are currently no data available covering the whole itinerary, just batches of localised data often

with geographical and temporal restrictions. To overcome this issue, as part of the CSA, a mathematical framework is being developed to complete the missing information. This framework consists of two main elements: a set of statistical tools (factor analysis, clustering, causality, etc.) to analyse the available data and a simulation engine (implemented in software, therefore also a data infrastructure).

Both components have different requirements and integrate with data differently. This section establishes the first set of model requirements and integration with the data as result of having identified the available data sources and their characteristics.

4.2.2 Data analysis

Data analysis is the process of inspecting data with the purpose of obtaining useful information. However, raw data usually requires cleaning, transforming or summarising.

Factor analysis is a fundamental tool to reduce the number of variables and therefore making the datasets more accessible. Factor analysis searches for unobserved variables, which are combinations of observed variables, describing rightfully the dataset (i.e. keeping the same properties). Factor analysis can also be used with partial datasets to check for integrity and stability of the data.

Clustering techniques, on the other hand, group variables with similar characteristics into classes, creating a partition of the variable space. If the elements in each class are similar enough all the elements in the class can be substituted by a representative element (i.e. standard element). Having representatives usually reduce the number of cases to be explored and allows other data sources to be extrapolated into elements of the same class, provided classes are invariant in the new data source an hypothesis easily adopted.

Correlation and causality are two other tools fundamental to the data analysis. Correlation determines how strongly two variables are related, whilst causality (i.e. Granger's Causality) implies directional relation between a cause and an effect. Discovering causalities and correlations help to gain a deeper understanding of the underlying system of which the data was extracted.

An outlier is an element in the data sample, which is far away from the rest of the samples; detection techniques (e.g. extreme values analysis) help to identify these elements. Most times outliers are attributed to measurement errors and discarded. In any case outliers, if not discarded, should be threated differently as they may reveal particularities of the system (e.g. Black Swan or Dragon King).

4.2.3 Modelling approach

Available data does not cover the whole European air transportation system, so in order to assess mobility and fill the gaps of unavailable data a model will be used. The key aspects of this model are:

- Event-driven simulation paradigm: simulation flow is determined by a series of *events* processed by a *stack manager* unit. This allows the model to break-down the

journey into smaller phases, simpler to model using real data or reproducing the actual system behaviour.

- Complexity Science: the model follows a bottom-up approach, in which smaller elements and their interactions are modelled and the overall behaviour is then determined, in some cases with (*a priori* unexpected) emergent behaviours.
- Stochastic model: many data sources are collections of (descriptive) statistics, the model is prepared to incorporate those statistics. In addition, the model is able to work with partial information, providing in that case partial answers as well.
- Layered network: the underlying basic model is a graph model in with interacting elements and feedback loops organised into layers.

4.2.4 Infrastructure (systems) integration

Many data sources are in different formats, platforms and technologies not completely compatible. The solution in the DATASET2050 CSA will be to create a cloud repository, managed by the consortium partners that contains either the cleaned, exported relevant data sources or connectors to external databases.

In any case the objective of the infrastructure is to homogenise the data sources and provide a frontend much easier to handle. Due to possible confidentiality issues all data will be processed on the cloud, so it will not be necessary to download complete datasets. Access will be monitored and limited by nominal user accounts and when required data will be stored in encrypted format.

After analysing several alternatives Amazon Web Services provides the most complete ecosystem to create the necessary infrastructure: RDS for storage SQL databases, S3 for massive raw data, EC2 for processing power and IAM for access management and users administration.

4.3 Integration with mobility metrics

Passenger-centric metrics are still largely absent from the air transport system performance framework, for example, delay calculations are usually provided in terms of flight delay. The SESAR WP-E POEM project demonstrated how flight and passenger delays are not equivalent (POEM, 2013).

DATASET2050 is taking a customer-centric approach with quantitative assessments focused on the passenger. The metrics and indicators used will provide an assessment of European mobility in the context of the 4 hours door-to-door goal. This should help us to understand the implications of policy strategies and the trade-offs between them, as well as identifying opportunities for improvements.

The development of such mobility metrics needs to be fully aligned with the availability of data – work in WP2 will continue to develop the model capable of providing reliable metrics. WP5 will define the mobility metrics covering performance at the macroscopic level and at a lower scale. Examples include:

High-level/macroscopic performance indicator:

- Passenger 4 hours door-to-door metric (including distributions thereof, i.e. not just focused on mean values or 90th percentiles)

Lower-level performance indicators:
- Airport accessibility;
- Airport processes;
- Connectivities (and comodalities);
- Frequencies between origins and destinations.

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6. Acronyms, abbreviations

- ACARE: Advisory Council for Aviation Research and Innovation in Europe
- ACC: Area control centre
- ASKs: Available seat kilometres
- ATS: Air traffic services
- BHL: Short name of DATASET2050 partner: Bauhaus Luftfahrt
- CAA: Civil Aviation Authority
- CBD: Central business district
- CSA: Coordination and Support Action
- DDR2: Demand Data Repository (second phase)
- DLR: Deutsches Zentrum für Luft- und Raumfahrt e.V.
- DX.Y: Deliverable's name (X=workpackage, Y=deliverable numbering within workpackage)
- EC: European Commission
- ECTL: Short name of DATASET2050 partner: EUROCONTROL
- EEA: European Economic Area
- EFTA: European Free Trade Association
- ERTMS: European Rail Traffic Management System
- EU: European Union
- EU-28: European Union 28 member countries (since July 2013)
- GDP: Gross domestic product
- GHG: Greenhouse gas
- GIS: Geographic information system
- H2020: Horizon 2020 research programme
- HS2: High Speed 2 (planned rail link)
- HS3: High Speed 3 (proposed rail link)
- ICT: Information and communication technology
- IFR: Instrument flight rules
- INX: Short name of DATASET2050 coordinator: Innaxis
- ITS: Intelligent Transport Systems
- LCC: Low-cost carrier
- LSSIP: Local Single Sky ImPlementation
- MCT: Minimum connecting time
- mppa: Million passengers per year
- NUTS: Eurostat's hierarchical classification of spatial units (NUTS1 - NUTS3)
- O&D: Origin and destination
- OECD: Organisation for Economic Co-operation and Development
- PAV: Personal air vehicle
- R&D: Research and development
- RIS: River information services
- RPKs: Revenue passenger kilometres
- SESAR: Single European Sky ATM Research
- SRIA: Strategic Research and Innovation Agenda
- UNSD: United Nations Statistical Division
- UOW: Short name of DATASET2050 partner: University of Westminster
- USD: United States dollar
- VFR: Visiting friends and relatives
- WP: Workpackage