# DATASET2050

## “Data driven approach for a Seamless Efficient Travelling in 2050”

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## Deliverable 4.2
## “Future Supply Profile”

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# Abstract

The purpose of this document, Deliverable 4.2, is to describe the future supply profile of EU mobility in the context of air transport. This includes, but is not restricted to, the evolution of the different travel services detailed in earlier DATASET2050 tasks and their corresponding trade-offs. This deliverable and associated tasks feed the model quantitatively and qualitatively via WP5, representing a key milestone for the DATASET2050 model.

With prior agreement, this report has been delivered in April 2017, later than scheduled in the Grant Agreement, but provoking no further delay to DATASET2050's milestones and deliverables.

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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, 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 objective of DATASET2050 is to provide **insights into the door-to-door** European travel paradigm for the current, 2035 and 2050 transport scenarios, through a data-driven methodology;
- DATASET2050 puts the **passenger at the centre**, paving the way for a seamless, efficient door-to-door travelling experience. The main focus to analyse 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);
- DATASET2050 addresses the **main transport mobility goal** stated in the Flightpath 2050: 90% of travellers within Europe are able to complete their journey, door-to-door within four hours. Through the application of statistical analyses, multi-modal mobility modelling and predictive analytics, DATASET2050 will compute the **current status** of air transport mobility across Europe;
- The analyses will enable the identification of **transport bottlenecks** in the current scenario and across different future 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 will highlight **research needs and requirements towards the four-hour door-to-door goal** formulated by ACARE. Due to the multi-dimensionality of the problem, DATASET2050 will use visualisation techniques, to ease understanding of the results;
- DATASET2050 partners are supported by an Advisory Board, made up of key **European transport stakeholders**;
- The **dissemination and communication** plans ensure efficient circulation of results among key European transport policy makers and stakeholders. The plans also incorporate their valuable input and perspectives, obtained during the project workshops.

## 1.2 WP4 and Deliverable 4.2 context

DATASET2050 WP3 is devoted to the mobility demand profile (customers, demographics, passenger profiles, etc.), with a deliverable on current status (D3.1) and one on the future scenarios, namely 2035 and 2050 (D3.2). In a symmetric approach, WP4 tackles the current and future European transport supply side for passenger journeys. WP4 is also divided into

D4.1 on the current supply status (already submitted) and this deliverable (D4.2) that considers the future supply profile.

The aim of WP3 and WP4 deliverables is twofold: on one hand providing insight on the different profiles and processes at the different timeframes. On the other, feeding the WP2/WP5 model with qualitative and quantitative information regarding the transport processes. This enables the ulterior simulation and computation of the door-to-door metrics.


**Figure 1: Relationship between DATASET2050 deliverables**

## 1.3 Deliverable structure and content

D4.2 consists of the following sections:

- Introduction to the DATASET2050 project, WP4 and D4.2 context;
- Definitions and archetypes;
- Analysis by phase and high-level group;
- Advancing the model;
- Data management and outputs for WP5;
- Acronyms, abbreviations, references, appendix.

# 2. Definitions and archetypes

## 2.1 Defining the high-level factors

As a basis for the analysis of future supply as well as demand profiles within DATASET2050, this section identifies **high-level factors** that shape potential future development paths and are hence relevant for the analysis of implications for the four hours door-to-door process. In order to attain a set of valid and accepted factors, the approach taken here comprises the analysis of different studies concerned with future development. Therefore, the following analysis attains a more comprehensive and thorough picture of the future environment and its drivers.

As can be seen in Figure 2, multiple scenario studies are collected in the first step, i.e. studies that focus on the analysis of differentiated future alternatives. All these studies have in common that they consider a set of factors that are likely to have an influence on various sectors such as politics, economics, or regulation. In a second step, the influencing/underlying factors in each study are identified. These may include, for example, urbanisation, or the level of technological innovation. Since all studies focus on slightly different aspects, all these factors are aggregated in order to maintain a comprehensive list across all studies (step 2 in Figure 2).


Figure 2: High-level factor identification process

The analysis of interdependencies (step 3) is conducted in order to see which future developments are considered to influence others in a very strong way or vice versa. The degree of interdependency between different factors as well as the level of influence will also impact the consideration of factors for the analysis within DATASET2050 (step 4). Each of these steps will be further elaborated below.

### 2.1.1 Selection of studies

In the first step, an in-depth literature review is conducted and 16 high-quality scenario studies are considered (Table 1). The criteria for selection include that the studies should (1) have a similar time horizon as defined in the project with the years 2035 and 2050, (2) cover a wide range of possible future paths and (3) have a specific mobility focus with relevance to the project. The background of the studies is diverse, ranging from government reports to corporate studies and publications from associations and think tanks, hence representing diverse perspectives.

**Table 1: Scenario collection (own depiction)**

| Scenario study | Time horizon | Study type / background |
|---|---|---|
| European Commission (2012) | 2050 | Government |
| Deutsche Post AG (2012) | 2050 | Corporate |
| Randers (2012) | 2050 | Think Tank |
| CONSAVE (2005) | 2050 | Research |
| IATA (2011) | 2050 | Association |
| World Energy Council (2012) | 2050 | Corporate |
| Fouré *et al.* (2012) | 2050 | Research |
| Owen *et al.* (2010) | 2050 | Research |
| Vorster *et al.* (2013) | 2050 | Research |
| ORIGAMI (2013) | 2030 | Research |
| TOSCA (2011) | 2050 | Government |
| Shell (2008) | 2050 | Corporate |
| Pfaffenbichler *et al.* (2012) | 2050 | Research |
| EUROCONTROL (2013 a,b) | 2035, 2050 | Association |
| Phleps *et al.* (2015) | 2035 | Research |
| TU Munich (2013) | 2050 | Research |

### 2.1.2 Identification of underlying factors

Each study contains factors or drivers that might affect the future world in one way or another. Examples include 3D printing (Deutsche Post AG, 2012), population growth (IATA, 2011), life expectancy (IATA, 2011), or changing customer needs (IATA, 2011). To organise the data in a structured way and to compare the different studies, each study is disaggregated into single pieces and then re-aggregated into a uniform structure. Firstly, an in-depth review is conducted and all factors from the studies are gathered and clustered according to the STEEP-M analysis framework. STEEP-M is an acronym for social, technological, economic, environmental, political and mobility, e.g. the driver "urbanisation" is assigned to the category S (social). The STEEP-M framework has been selected since we can capture and structure a high amount of factors affecting demand for and supply of the future European transport system.

An example of the results of the factor structuring is depicted below. Table 2 shows the category S (social) and the included factors. Each factor is defined (see right hand column) and assigned with one or multiple projections. The projections describe which particular directions a factor might take in the future. Taking the factor "social well being", for example, it ranges from a low to a high level of social well being. A low level of social well being therefore means that citizens are not satisfied with aspects such as housing, jobs, health, or work-life balance in the region or country they live in. The complete table with all results from the STEEP-M clustering can be found in Appendix 1.

**Table 2: Example scenario structuring: social factors (own depiction)**

| STEEPM | Factor | Projection | Definition projection | Definition factor |
|---|---|---|---|---|
| Social | Ageing population | Increasing | Median age is increasing (world) | Increasing overall life expectancy and decreasing birth rates lead to a growing share of elderly people (> age 60) in the total population, global birth rate drops below an average of 2.1 kids per woman in 2050, working-age population (ages 20-59) will grow more than 25% between 2010 and 2050, population in emerging markets is younger than in industrialized countries |
| | Population growth | Increasing | Total amount of people is increasing (world) | Population grows further over the next decades, stabilization at a level of 9 to 10 billion is expected by 2055, growth is driven by Asian and African countries, Europe and Northern America experience a stagnation/ very low level of population growth |
| | Social well being | High level | Citizens are highly satisfied with the addressed aspects | This factor is based on the OECD "Better Life Index" and addresses the following aspects: housing, jobs, community, education, civic engagement, health, life satisfaction, safety, work-life balance (http://www.oecdbetterlifeindex.org/#/14411144541) |
| | | Medium level | Citizens are satisfied with only part of the aspects | |
| | | Low level | Hardly any or none of the aspects are satisfactory for citizens | |
| | Middle class development | Increasing share | Amount of people belonging to middle class increases | Middle class income is defined to range from USD6,000 to USD30,000 p.a., the middle class development strongly depends on India and China and people belonging to the middle class are predicted to rise from 400million people (2005) to more than 1billion people (2030), more than 90% will live in emerging and developing countries |
| | | Stagnation | Amount of people belonging to middle class stagnates | |
| | | Decreasing share | Amount of people belonging to middle class declines | |
| | Urbanization | Increasing | The share of people living in urban areas as well as the urban sprawl are increasing | More people in absolute terms and in relation to rural areas are living in urban areas, increased land use for urban sprawl and urban areas are more densely populated (people living in urban areas with >500T: increase from 25% (2011) to 33% (2025), cities with more than 10 million people: increase from 23 (2011) to >30 (2025)) |

With each factor and assigned projections described, we analyse how frequently each factor is addressed or mentioned in the considered studies. This provides another good indicator about the importance of each factor. World economic development, innovation and emissions, for example, occur the most across all studies. In contrast, global collaboration in research and development (R&D), middle class development, and urbanisation occur the least, as can be seen in Figure 3. Here, the number above each bar chart indicates how many times each factor is addressed or mentioned across all studies in Table 1.

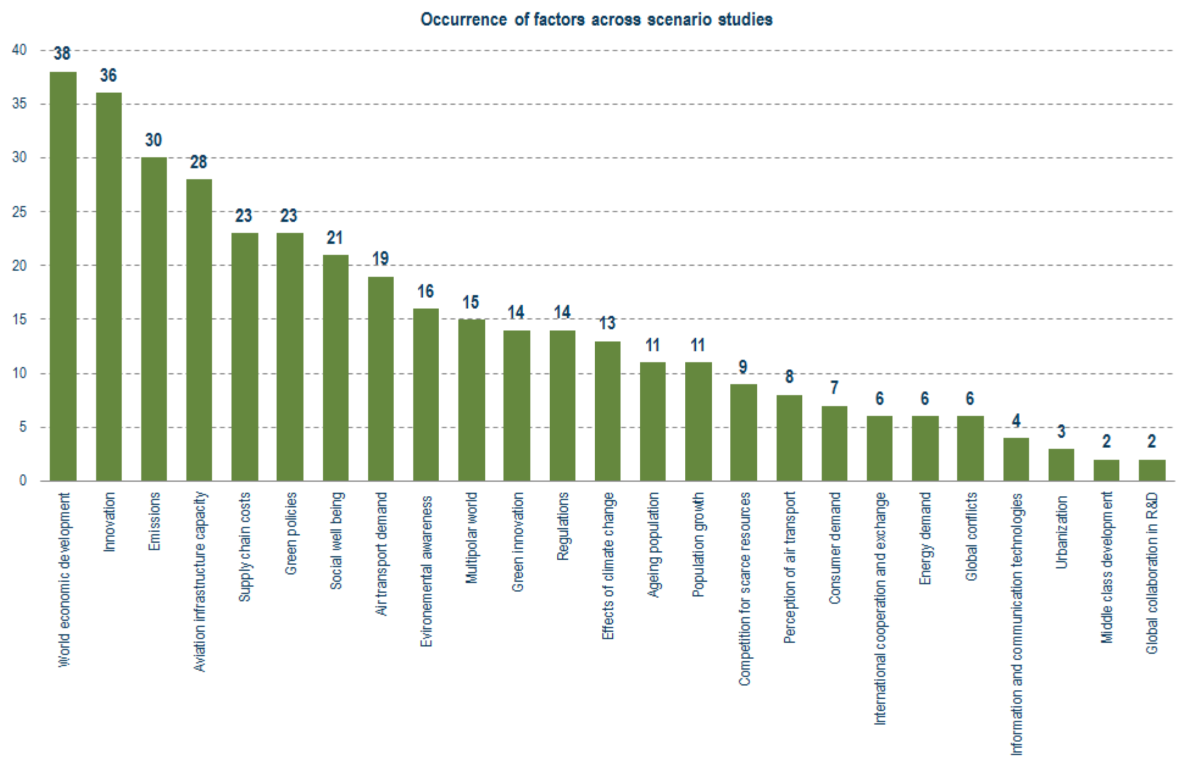



**Figure 3: Occurrence of factors in order of frequency (own depiction)**

### 2.1.3 Analysis of interdependencies

In order to understand the interdependencies between the selected factors in a better way we conduct a cross-impact analysis. Within a cross-impact analysis, two factors are linked by considering their mutual influence on each other. Taking urbanisation and middle class, for example, we first analyse the degree of influence of urbanisation on the development of the middle class, i.e. “0” means that there is no influence, “1” there is a weak influence, and "3" depicts a strong influence. As a next step, the impact of the middle class on urbanisation is determined. The assessment here is based on both experts' assessment as well as a detailed literature review on different dependencies. Conducting this analysis for all factors yields the results shown in Figure 4. Here, the level of influence of each factor on the different categories within STEEP-M is illustrated. Taking the example of urbanisation again, we see that the overall influence on all categories together is medium to high compared to all other factors. Furthermore, the influence on the political category and the respective factors included here is smallest compared to other categories. That means that direct linkages between urbanisation and political aspects are not as strong as in other fields. This analysis yields the input for the development of the DATASET2050 high-level factors.

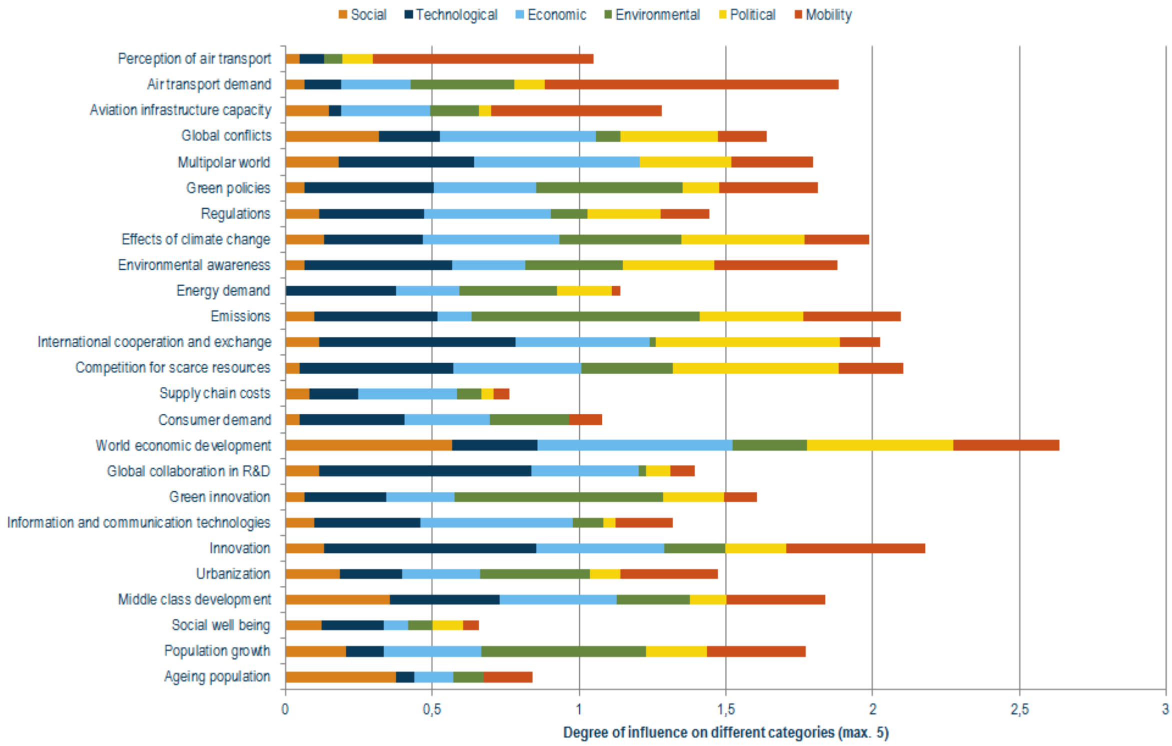



**Figure 4: Results of cross-impact analysis (own depiction)**

Another way of illustrating the results of the cross-impact analysis is shown in Figure 5. Each factor is ranked according to its influence on other factors (x-axis) and to the degree it is influenced by other factors (y-axis). World economic development is the factor which has the highest interdependence with other factors, i.e. has the highest influence on other factors and is highly influenced by other factors.


**Figure 5: Identification of main drivers (own depiction)**

### 2.1.4 Grouping of DATASET2050 high-level factors

In order to obtain a manageable set of indicators for the analysis of future scenarios and implications within DATASET2050, we will further aggregate the identified factors in three high-level factor groups. The factors previously identified across the different scenarios serve as a basis to analyse the future development in various areas affecting the future supply of the European transport system. Some of these factors are also relevant for the analysis of future demand and will hence also be addressed in the parallel report on future demand profiles, e.g. ageing population or middle class development.

- **H1. Traffic / demand:** Factors and indicators in the context of transport demand, urbanisation, demographics, society and passenger profiling;
- **H2. Market forces / technologies / supply:** All the factors linked with the market forces, the environment, innovation, research and new tools;
- **H3. Policy / regulation:** Devoted to all the international, regulation, policies, global conflicts aspects etc.

**Table 3: Grouping of DATASET2050 high-level factors**

| H1. Traffic / demand | H2. Market forces / technologies / supply | H3. Policy / regulation |
|---|---|---|
| Ageing population | Innovation | International cooperation |
| Population growth | Information and communication technologies | Effects of climate change |
| Social well being | Green innovation | Regulations |
| Middle class development | Global collaboration in R&D | Green policies |
| Urbanisation | Supply chain costs | Multipolar world |
| Consumer demand | Competition for scarce resources | Global conflicts |
| Energy demand | Emissions | Perception of air transport |
| Environmental awareness | | |
| Aviation infrastructure capacity | | |
| Air transport demand | | |

These three groups and the resulting implications for the supply side are analysed in more detail in the following sections.

## 2.2 Defining the archetypes

### 2.2.1 Passenger archetypes

In considering how the passenger of the future might look, the factors that drive air transport demand and passengers' travel behaviour – including the future development of these drivers for 2035 and 2050 – have been explored, enabling a range of passenger archetypes to be developed for the project. The final passenger archetypes for 2035, also referred to as passenger profiles, are summarised in this section – please refer to D3.2 for full reporting, including the implications for 2050 passenger archetypes.

Six passenger archetypes have been developed: *Cultural Seeker*, *Family and Holiday Traveller*, *Single Traveller*, *Best Agers (Next Generation)*, *Environmental Traveller* and *Digital Native Business Traveller*. These archetypes differ by main travel purpose (private, 'bleisure' – business trips combined with leisure, and business), predominant age group, income level (low, medium, high) and several other characteristics. Table 4 summarises their main attributes.

**Table 4: Future passenger archetypes and their characteristics**

| | Passenger archetype | | | | | |
|---|---|---|---|---|---|---|
| | **Cultural Seeker** | **Family and Holiday Traveller** | **Single Traveller** | **Best Agers (Next Generation)** | **Environmental Traveller** | **Digital Native Business Traveller** |
| **Main travel purpose** | Private | Private | Private | Private | Bleisure[1] | Business |
| **Age group** | 15-65 | 30-50, and children under 15 | 44+ | 65+ | 30-44 | 24-64 |
| **Trips per year per capita** | 0.5-1.5 | 0.5-1.5 | 0.25-0.5 | 0.5 | 0.5 | 0.5-1.5 |
| **Travel party size** (number of people) | 1-2 | 2-3 | 1 | 1-2 | 1-2 | 1-2 |
| **Income level** | Medium-high | Medium-high | Low-medium | Medium | Medium | Medium-high |
| **Travel expenditure** | Low-medium | Medium | Low | Medium | Low | Medium-high |
| **Use of mobile devices and retrieval of information** | High frequency | Medium frequency | Medium frequency | Medium frequency | Low-medium frequency | High frequency |
| **Airport access mode** | Public transport, taxi, car sharing | Public transport, car (park and travel) | Public transport, kiss & fly[2] | Car (park and travel), kiss & fly[2] | Public transport, car sharing, cycling | Public transport, taxi, car sharing |
| **Luggage** | Usually hand luggage | Usually check-in | Usually hand luggage | Usually check-in | Usually hand luggage | Usually hand luggage |

[1] Bleisure: business trips combined with leisure.
[2] Drop-off and pick-up by friends and relatives.

### 2.2.2 Airport archetypes

This section introduces some of the standard airport categorisations that are available, and explains how the new archetypes have been defined for the DATASET2050 model.

#### *2.2.2.1 Existing airport categorisations*

The criteria used to categorise or group airports vary, though typically they are based on either annual passenger numbers or particular operational characteristics, such as aerodrome firefighting capability or reference field length (ICAO, 2016). In the context of performance needs, the ATM Master Plan's airport 'Operating Environment' classifies airports by their utilisation and surface layout complexity (undefined), allocating 85 airports into four groups (SESAR, 2017).

**Table 5: ATM Master Plan airport classification**

| Airport category | Utilisation | Surface layout complexity |
|---|---|---|
| LUSL | Low utilisation airports<br>(<90% utilisation during 1 or 2 peak periods a day) | 'Simple' |
| LUCL | Low utilisation airports<br>(<90% utilisation during 1 or 2 peak periods a day) | 'Complex' |
| HUSL | High utilisation airports<br>(>90% utilisation during 3 or more peak periods a day) | 'Simple' |
| HUCL | High utilisation airports<br>(>90% utilisation during 3 or more peak periods a day) | 'Complex' |

The Commission has combined two existing EU airport classification schemes (guidelines for the development of the trans-European transport network and categories used by the Committee of the Regions) to produce guidelines on financing airports (European Commission, 2005). These airport classifications are based on annual passenger numbers and are compared in Table 6.

**Table 6: Comparison of three EU airport classifications**

<table>
<tr><th rowspan="2">Total passengers per year[1]</th><th colspan="2">(1) Trans-European transport network – three categories of airport</th><th colspan="2">(2) Committee of the Regions – five categories of airport</th><th rowspan="2"></th><th colspan="2">(3) European Commission guidelines – four categories of airport</th></tr>
<tr><th>Description</th><th>Passenger groups</th><th>Description</th><th>Passenger groups</th><th>Description</th><th>Passenger groups</th></tr>
<tr><td>Over 25 million</td><td rowspan="3">International connecting points</td><td rowspan="3">>=5 million</td><td>Major hub airports</td><td>>25 million</td><td rowspan="5">→</td><td rowspan="2">Category A: large community airports</td><td rowspan="2">>10 million</td></tr>
<tr><td>10 to 25 million</td><td>National airports</td><td>>10 <=25 million</td></tr>
<tr><td>5 to 10 million</td><td>15 airports</td><td>>5 <=10 million</td><td>Category B: national airports</td><td>>5 <=10 million</td></tr>
<tr><td>1 to 5 million</td><td>Community connecting points</td><td>>=1 <5 million</td><td>57 airports</td><td>>1 <=5 million</td><td>Category C: large regional airports</td><td>>1 <=5 million</td></tr>
<tr><td>Up to 1 million</td><td>Regional connecting points and accessibility points</td><td>>=250k <1 million</td><td>67 airports</td><td>>=200k <=1 million</td><td>Category D: small regional airports</td><td><=1 million</td></tr>
</table>

[1] For illustrative purposes, i.e. overlaps exist between passenger categories.

ACI EUROPE use four airport groups based on annual passenger numbers for statistical reporting (ACI EUROPE, 2016a). These groups are well established, offering convenient categories for research purposes and have been used as the starting point for defining the project's airport archetypes (see Table 7).

**Table 7: ACI EUROPE airport traffic categories**

| Airport groups | Total passengers per year | Examples |
|---|---|---|
| Group 1 | >25 million | Amsterdam Schiphol, Madrid-Barajas |
| Group 2 | >10 <=25 million | Athens International, Stockholm Arlanda |
| Group 3 | >5 <=10 million | Berlin Schönefeld, Gothenburg Landvetter |
| Group 4 | <=5 million | Belfast International, Sofia International |

Total passenger data (terminating and transfer passengers) per airport in 2015 have been sourced from ACI EUROPE (personal communication). From these, the top 200 ranked airports within 32 European countries – the current EU-28 member states plus the four European Free Trade Association (EFTA) countries – are in scope for the project (refer to D2.1 for further details).

ACI EUROPE also publish an annual European air connectivity report, scoring airports by their direct, indirect and hub connectivity according to schedule data (ACI EUROPE, 2016b). Airports with the highest levels of connectivity are grouped as:

- 'The Majors': the top airports in terms of hub connectivity, e.g. Frankfurt Main;
- 'Secondary Hubs': airports that are the 'Come Back hubs' (recovering/protecting their market position after an earlier de-hubbing process), e.g. Rome Fiumicino; and airports which have made significant gains in hub connectivity since 2006, termed the 'New Kids on the Block', e.g. Düsseldorf.

Airports with lower levels of hub connectivity are grouped as:

- 'Niche & Aspiring Hubs': airports previously not considered hubs, but developing a niche position such as connecting regional flows, e.g. Keflavik International;
- 'The Challenged Hubs': those airports which have lost significant hub connectivity since 2006. These include 'De-hubbing' airports, e.g. Milan Malpensa, and 'Weakened Hubs' such as Copenhagen Kastrup. Note, passenger numbers may still be increasing at these airports, however their connectivity options have reduced considerably over the last decade.

As might be expected, there is a degree of overlap between the busiest airports, and airports with the highest levels of connectivity. For example, five of the six busiest EU-28/EFTA airports are also 'The Majors'. The top four airports (London Heathrow, Paris Charles de Gaulle, Frankfurt Main and Amsterdam Schiphol) are also identified as the major European hubs in the findings of the UK's Airports Commission (Airports Commission, 2015). Figure 6 shows the top 200 EU-28/EFTA airports by ACI EUROPE group, with their current connectivity classification.

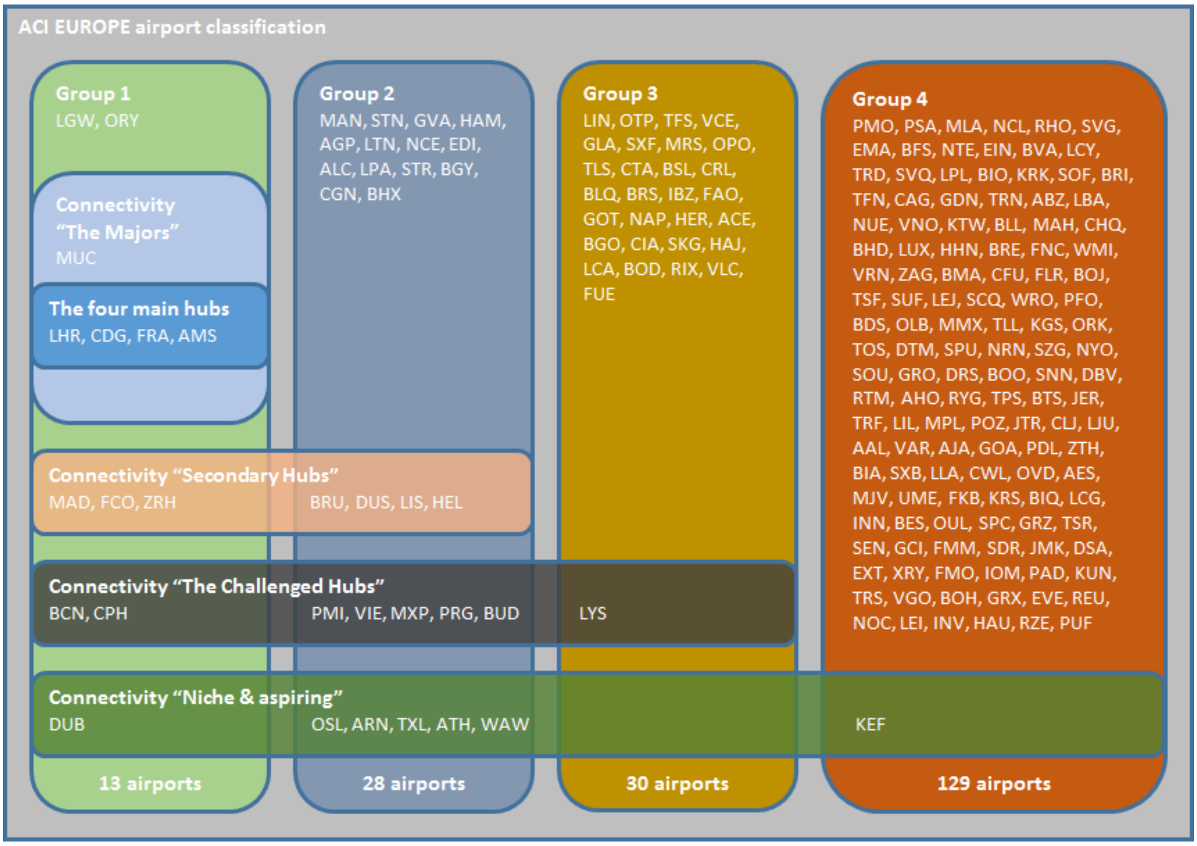



**Figure 6: ACI EUROPE airport traffic categories with connectivity classifications for the top 200 EU-28/EFTA airports (own depiction)**

### *2.2.2.2 New airport archetypes*

The characteristics of airport archetypes have been scoped in earlier deliverables, for example D2.2 and D4.1 considered treating a small number of large airports individually, with the remaining airports in the top 200 grouped into generic profiles. Further investigation has since confirmed that insufficient current (2015) data are available to model the largest airports individually and covering all processes (e.g. access times). Hence archetypes are required to cover the profiles of all 200 airports in scope for the processes where no individual data is available.

Four airport archetypes have been developed, based on current (2015) ACI EUROPE passenger and connectivity data, and recent data from other sources. Note that airport migration between the following current archetypes will be considered for the 2035 and 2050 timeframes, as will the addition of new airports (e.g. Berlin Brandenburg will eventually replace Berlin Tegel).

**Airport archetype (1) 'main hub'**

This group covers the key hub airports, of which four have been included: London Heathrow, Paris Charles de Gaulle, Frankfurt Main and Amsterdam Schiphol.

These airports are classified as the four main EU hubs (Airports Commission, 2015), as operated by British Airways (oneworld), Air France-KLM (SkyTeam) and Lufthansa (Star Alliance), and are the top four ranked airports within ACI EUROPE's Group 1 (>25m passengers p.a.), accounting for almost 20% of EU-28/EFTA passengers in 2015. They have been identified by ACI EUROPE's 2016 connectivity report as having a high level of hub connectivity ('The Majors'), confirmed by an overall average of 41% of their passengers transferring between flights.

**Airport archetype (2) 'secondary hub'**
This group captures the secondary level of hub airports: Madrid-Barajas, Munich, Rome Fiumicino, London Gatwick, Barcelona El Prat, Paris Orly, Copenhagen Kastrup, Zürich, Dublin, Brussels National, Düsseldorf, Lisbon Portela and Helsinki Vantaa.

These include airports classed as 'Secondary Hubs' by ACI EUROPE's 2016 connectivity report, with the addition of Munich (classed as one of 'The Majors'). (Note that Munich was considered for inclusion in the main hub archetype, but has recently slipped to eighth in the 2016 passenger rankings among EU-28/EFTA airports (ACI EUROPE, 2017)). Overall, 17% of passengers are transfer passengers. In addition, the five remaining ACI EUROPE Group 1 airports (>25m passengers p.a.) not captured under the hubbing classification are also included (note that two are 'Challenged Hubs'). The 13 secondary hub archetype airports accounted for approximately a quarter of EU-28/EFTA passengers in 2015.

**Airport archetype (3) 'large/medium'**
The third group covers the next tier of busy airports: Oslo Gardermoen, Palma de Mallorca, Manchester, Stockholm Arlanda, Vienna International, London Stansted, Berlin Tegel, Milan Malpensa, Athens International, Geneva International, Hamburg, Málaga, London Luton, Nice Côte d'Azur, Prague Václav Havel, Warsaw Frederic Chopin, Edinburgh, Alicante, Gran Canaria, Stuttgart, Milan Orio al Serio, Cologne Bonn, Budapest Ferihegy, Birmingham, Milan Linate, Venice Marco Polo and Berlin Schönefeld.

Apart from a few exceptions, these airports handled up to 25 million passengers in 2015 (ACI EUROPE's Group 2 airports, >10 <=25m passengers p.a.) and include an even split between 'Niche & Aspiring Hubs' and 'The Challenged Hubs', if categorised. A few Group 3 airports have been added to this group – airports with a high utilisation operating environment as specified by the ATM Master Plan (see Table 5) and just below the archetype (3) passenger threshold (e.g. Milan Linate), plus Berlin Schönefeld which has shown recent high passenger growth, having joined Group 2 airports in 2016 (ACI EUROPE, 2017). Overall, the 27 large/medium archetype airports accounted for approximately a quarter of EU-28/EFTA passengers in 2015, although only 6% were transfer passengers.

**Airport archetype (4) 'national/regional'**
The final archetype covers the remaining 156 EU-28 and EFTA airports ranked in the top 200, which have not already been included in archetypes (1) to (3).

These airports are either ACI EUROPE Group 3 (>5 <=10m passengers p.a.) or Group 4 (<=5m passengers p.a.). An airport that may need to migrate to another archetype for the future scenarios is Keflavik International – the only 'niche' airport in this group, it has experienced very high passenger growth recently partly driven by the rapid growth of WOW air.

In 2015, almost 30% of EU-28/EFTA passengers used these airports, with only 4% transferring flights.

The following table summarises the key attributes of the four airport archetypes.

**Table 8: Airport archetypes and their characteristics**

| Archetype characteristic | Archetype description | | | |
|---|---|---|---|---|
| | (1) Main hub | (2) Secondary hub | (3) Large/medium | (4) National/ regional |
| **Number of airports (percentage of EU-28 & EFTA passengers[1])** | 4 airports (17% of passengers) | 13 airports (26% of passengers) | 27 airports (26% of passengers) | 156 airports (29% of passengers) |
| **Average proportion of transfer passengers[2] (range)** | 41% (31-57%) | 17% (up to 36%) | 6% (up to 28%) | 4% (up to 33%) |
| **Ratio of international:domestic passengers (range of international passengers)** | 0.93:0.07 (89-100%) | 0.84:0.16 (63-100%) | 0.79:0.21 (48-100%) | 0.62:0.38 (0-100%) |
| **Ratio of intra-EU:extra-EU passengers[3] (range of intra-EU passengers)** | 0.50:0.50 (41-57%) | 0.75:0.25 (67-84%) | 0.82:0.18 (63-100%) | 0.90:0.10 (40-100%) |
| **ACI EUROPE group** | Group 1 (>25m pax p.a.) | Remaining Group 1 (>25m pax p.a.); Group 2 (>10 <=25m pax p.a.) | Mainly Group 2 (>10 <=25m pax p.a.); few Group 3 (>5 <=10m pax p.a.) | Group 3 (>5 <=10m pax p.a.); Group 4 (<=5m pax p.a.) |
| **ACI EUROPE connectivity** | All 'The Majors' | Remaining 'Major'; mainly 'Secondary Hubs'; small number of 'Niche & Aspiring'/ 'Challenged' hubs | Most of the 'Niche & Aspiring'/ 'Challenged' hubs; most without connectivity classification | No connectivity classification; remaining 'Niche & Aspiring'/ 'Challenged' hubs |

[1] Top 200 airports account for 97% of EU-28 and EFTA passengers in 2015.
[2] Transfer data compiled from various sources; available for approximately 50% of airports in scope.
[3] Intra-/extra-EU passengers only available for EU-28 airports.

### 2.2.3 Airline archetypes

Airlines can be differentiated by attributes such as their business model, fleet composition, alliance membership and geographic coverage. In DATASET2050, airlines archetypes are defined based on business model criteria, with four airline archetypes used by the model: *full-service*, *low-cost*, *regional* and *charter* airlines. These categories capture recognised airline operator business types, and are regularly employed by research projects, such as the recent SESAR WP-E POEM and SATURN projects (SESAR, 2013; SESAR, 2015).

The characteristics of these four airline types to be modelled are outlined below. These are typical characterising features to be used in the DATASET2050 model, although the actual demarcation between these operator types is becoming rather less pronounced in many cases. Note that since DATASET2050 is focused on passenger mobility, cargo airlines are out of the scope.

**(a) Full-service airlines**

Full-service airlines, also known as network or legacy carriers, as in many cases they are inheritors of the former national airlines of many countries before privatisation. Their main features are:

- Hub-and-spoke strategy: allows them to offer a diversified network of routes, concentrated in one or more hub airports (distribution centre) and to base their traffic on a high number of connecting passengers;
- Different models of aircraft operated: with different capacities and ranges as result of their variety of routes;
- Multi-product strategy: with several classes in cabin (e.g. first class, business class and economy class), corresponding to different levels of service offered to the passenger;
- Wide variety of fares;
- Passenger loyalty programmes: frequent flyer programmes (FFPs);
- Participation in strategic (airline) alliances;
- High volume of sales through global distribution systems (e.g. Sabre).

Full-service airlines will behave differently depending on whether they are operating at or away from their hub airport(s). Any operation at the hub will have a lot of schedule flexibility, and will not consider alternative destinations. Away from the hub, the airline will be less flexible on the schedule, and more flexible with regards to the destination.

**(b) Low-cost carriers**

A low-cost carrier (LCC), low-fare or budget airline is determined by its target market, moreover aiming at a certain market segment determines a wide set of differentiating characteristics with respect to full-service or regional carriers. The LCC primary target market is passengers sensitive to price, offering the basic product, transportation, at the lowest possible fare. To compensate for the loss of revenue by tight ticket pricing, ancillary revenue has become an important financial attribute, i.e. charging extra for food, priority boarding, seat selection, check-in luggage, etc. These are the main LCC characteristics:

- Low fares, fewer traditional passenger services;
- Low yield, high volume;
- Low overhead cost (outsourcing);
- Bypass global distribution systems through internet distribution;
- Simplified ticket categories;
- Bundled and unbundled services;
- Short average flight lengths, high frequency;
- Avoidance of congested hub airports, alternative less congested airports preferred.

Low-cost carriers compete on prices and frequencies in short and medium range routes, with point-to-point traffic, offering very few different rates, sold mainly over the internet, giving a minimal service for a very low price. The reduction of the unitary cost is obtained not only by offering fewer services to the passenger, but also through a better utilisation of their productive means, minimising the diversity of aircraft they use (generally all their aircraft belong to the same model) and achieving greater flying hours per day (by greatly reducing the turnaround times).

**(c) Regional Airlines**

These companies specialise in passenger transport in, generally, short range routes, and for this reason, very often in domestic flights, or in the European case, intra-communitarian ones. They operate fleets of aircraft of the so-called regional models, with fewer than 100 seats. Some of them operate in an independent way, but the majority of them operate as franchisees or with some type of agreement with a full-service airline.

**(d) Charter**

Charter companies, originally from Europe, arose thanks to restrictive regulations in Europe that existed before 1993. They address a single segment of the market, tourism trips (vacations), and base their strategy on the sale of sets of seats to tour operators and travel agencies, who sell tickets to the passengers, often as part of a package (hotel, activities, etc.). Unlike other airlines which transport passengers with pre-established and regular frequencies and schedules, the charter companies offer their flights on-demand. Their load factor is usually very high, and the part of the package price attributed to the flight is at a rate considerably lower than that of regular flights (until the appearance of the low-cost carriers). Given the on-demand characteristic of charter airlines, they show some flexibility in schedule, however, they are very restricted in the economic aspect.

# 3. Analysis by phase and high-level group

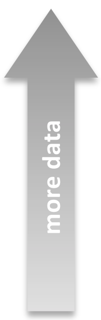
Having identified the high-level factors (Section 2.1), the future impacts of the evolution of traffic/demand (H1), market forces/technologies/supply (H2) and policy/regulation (H3) on the door-to-door mobility supply side are now considered. These follow the DATASET2050 sub-processes of **door-to-kerb** (and kerb-to-door), i.e. airport access/egress; **kerb-to-gate** (and gate-to-kerb), i.e. within the airport; and **gate-to-gate**, i.e. airside, including flight connections. For each sub-process, estimations are made of how each contributing factor, if implemented in 2035 and 2050, could support changes towards improving the door-to-door times of travellers. The net impact of these changes populate the summary tables in Section 5.1.

**Table 9: Model inputs and resolution**

| Scenario timeframe | Overview of model inputs | Model resolution |
|---|---|---|
| Current (2015) | Real data | Highly granular |
| Mid-term (2035) | Quantitative outcomes from running the model using 2015 data, with 2035 demand-supply forecasts<br>and<br>Qualitative assessments of how processes will evolve | Medium granularity |
| Long-term (2050) | Qualitative assessments of how processes will evolve | High level only |

As well as future impact estimations for each sub-process, the following sections also provide an overview of the available current data required by each airport archetype. To assist the reader, a score is assigned to each broad group of data (e.g. door-to-kerb access time) – the *lower* the score, the *more* data that are available.

Data availability rating:




1 Explicit data (n > 500) for at least 40% of airports;

2 Explicit data (n > 500) for at least 20% of airports;

3 Minimum, maximum, average times(/percentages) for at least 20% of airports;

4 Minimum, maximum, average times(/percentages) for at least 10% of airports;

5 Average times(/percentages) for at least 3 airports;

6 Average time(/percentage) for 1 airport;

7 Less.

For example, a score of "2" for airport archetype (1) 'main hub', shows that a comprehensive dataset is available for at least 20% of airports within that group (i.e. one airport). In some instances, times have been calculated by the project team in the absence of real data (see calculated examples in D4.1).

Table 28 in Section 5.2 consolidates the available current data required by all journey phases.

## 3.1 Door-to-kerb

### 3.1.1 Current values

Table 10 gives an overview of the available current door-to-kerb data required by each airport archetype. Refer to Table 28 in Section 5 for a summary of available data for all journey phases.

**Table 10: Overview of the availability of current door-to-kerb data**

| Airport archetype | Door-to-kerb time (data availability rating[1]) | Kerb-to-door time (data availability rating) |
|---|---|---|
| (1) Main hub | mode split: average value (6)<br>access time: explicit dataset (2) | *derived from D2K* |
| (2) Secondary hub | mode split: average value (6)<br>access time: range of values (5) | *derived from D2K* |
| (3) Large/medium | mode split: average value (5)<br>access time: explicit dataset (2) | *derived from D2K* |
| (4) National/regional | mode split: average values (5)<br>access time: range of values (4) | *derived from D2K* |

[1] Data availability rating: the *lower* the score, the *more* data that are available (refer to Section 3).

### 3.1.2 Future impacts

#### *3.1.2.1 H1 traffic/demand*

The door-to-kerb journey is, at least in some areas, highly influenced by the volume and the type of demand for air transport.

An **ageing population** (but a constant demand) means that more passengers will favour certain types of transportation over others. More specifically, older people tend to avoid crowded areas like public transport to focus on taxis and personal cars. Since these types of transport offer shorter travel times on average for airport access, an ageing population could lead to a reduction in the average travel time.

**Population growth** leads directly to an increased demand volume for passengers. A purely volume increase has the main effect of increasing congestion across all means of transportation. Congestion leads to increased delays, so travel time is naturally increased when the volume of passengers increases. This is particularly true in areas where transportation is already congested, or near to their capacity limit.

Air transport demand has a similar effect to population growth. Even if an increase in air transport demand is constant with population growth, travel time might be increased due to higher congestion.

**Increased urbanisation** has the direct effect that on average, people will live in regions with better connectivity to airports, i.e. with reduced travel times to the airports, and thus reduce their travel time.

Finally, increased **environmental awareness** will likely lead to an increase in travel time, because quicker means of transportation are usually less environmentally friendly. As a consequence, passengers will overall choose more public transportation, emitting less pollution but increasing travel time.

#### *3.1.2.2 H2 market forces/technologies/supply*

The door-to-kerb journey is very open to different improvements and is thus difficult to make an exhaustive list of them. In Section 3.1.3 (Table 17 and Table 18) we have focused on the accessibility in terms on technological improvements linked to two main transportation systems for airports: trains and autonomous vehicles.

Regarding trains, the two main improvements expected for the airports are the increase in the frequency of the trains (for example at Luton) and their speed. Many express trains are already connecting major airports in Europe to the city centre, but the progressive development of high-speed rail is likely to have a big impact on some further locations. Indeed, many major cities are already connected via high-speed trains, in particular around the London-Frankfurt axis. These trains have three distinct effects:

- Increased competition for airlines;
- Decreased travel time for passengers using the line;
- Increased catchment areas.

As a consequence, the overall impact of the development of high speed trains is subtle and very difficult to forecast. When it comes to the travel time itself, it is not even clear if it will decrease or increase. Indeed, the higher speeds tend to decrease the travel times, but the increased catchment area will attract passengers which are further, like nearby cities – e.g. people from Lyon in France taking the plane in Paris. Moreover, the increased competition for airlines might lead to fewer short-haul flights and an increased demand for medium-haul flights. This last point is captured in the gate-to-gate discussion in Section 3.3.

The other major improvement expected in the future is the introduction of autonomous vehicles on a large scale. Their presence is foreseen to have many different impacts on the travel experience, including an overall better experience for the passenger. Moreover, the efficiency of autonomous vehicles will lead to a huge increase of the throughput for roads, hence decreasing congestion and the average travel time as well as the predictability of the travel time, leading to a further improvement by a decrease of the buffer time taken by passengers when flying.

#### *3.1.2.3 H3 policy/regulation*

**Overview**

As discussed in D4.1 (Section 3.5), there is no direct regulation or policy initiative at an EU level that directly relates to airport surface access and there is no indication that this will change in the future. Where national policies exist to improve surface access at airports they are being driven primarily due to forecast growth in air transport; the desire for more efficient, convenient and quicker accessibility with a better passenger experience; and a need to reduce harmful emissions. EU environmental regulation, notably related to climate change and ambient air quality, will play a major role with this latter factor, and thus policies to increase the use of public transport, and more efficient and smarter use of the car, are bound to become more popular. Publicly available data from a total of 51 European airports (corresponding to approximately 56% of European passengers) indicates that currently 43% of passengers use public transport (European Environmental Agency/EASA/EUROCONTROL, 2016), and so this is likely to increase in the future.

More general EU transport policy which will have an influence includes the *2011 Roadmap to a Single Transport Area,* which identifies the connection of all core network airports to the (preferably high speed) rail network by 2050 as one of its ten major goals (European Commission, 2011). Other relevant aspects of this policy relate to $CO_2$ reduction, improving air quality and the use of cleaner technology. As regards aviation, the *2015 New Aviation Strategy for Europe* recommends that there could be better airport integration with public transport operators, possibly being addressed in the framework of the Sustainable Urban Mobility Plans, the Covenant of Mayors or the European Innovation Partnership on Smart Cities and Communities (European Commission, 2015).

A number on individual countries have infrastructure or transport plans, which may or may not cover air transport and associated surface access plans. There may also be national or regional aviation plans, and master plans for airports. These indicate that in the future (as in the past) the nature and scale of surface access issues will vary from airport to airport, but generally the focus of these policies tends to be on the development of particularly rail, but also road schemes, and by improving airport on-site facilities such as rapid transit systems linking rail stations to terminals. It is very likely that environmental pressures to reduce the share of journeys by private car will continue, but this may cause conflict with commercial demands for airport operators to maximise the potential of car parking revenues. The practice of airport operators establishing mobility or surface access plans with associated targets through cooperation with different airport stakeholders seems set to become more popular, drawing on best practice in countries such as Norway, Sweden and the UK.

**Infrastructure or Transport Plans**

In terms of the physical development of airports and associated surface access projects at a national level, a number of countries have National Infrastructure or Transport Plans, but not all of these cover air transport, which partly reflects the increasing role of private sector ownership and market forces in aviation. Additionally, or alternatively, some countries have regional or local government plans. A key feature of a number of these is the need to provide rail access to airports, in some cases linking to the objectives of the 2011 EU Roadmap:

- *The Transport Policy of the Czech Republic for 2014-2020 with the Prospect of 2050* (Czech Ministry of Transport, 2013) highlights the need to connect the Václav Havel Airport in Prague to railway transport, both for direct connection of long-distance lines and for the connection to the city centre, and also to connect Brno and Ostrava airports to the railway infrastructure.

- *The Romania General Transport Master Plan* (Romania Ministry of Transport, 2014) comments on the lack of good public transport links connecting urban areas and Bucharest Henri Coanda Airport, with no direct rail, light rail or express bus connections to facilitate ease of movement. It states that a detailed feasibility study is required as part of a Sustainable Urban Mobility Plan to determine the need for a dedicated link.
- *The (Draft) Dublin Transport Strategy for the Greater Dublin Area 2016-2035* (National Transport Authority, 2015) proposes a light rail link to the airport called the New Metro North which would operate in a tunnel under Dublin City Centre. This would reduce travel time to less than one hour from the airport to the city centre (Figure 7 and Figure 8).

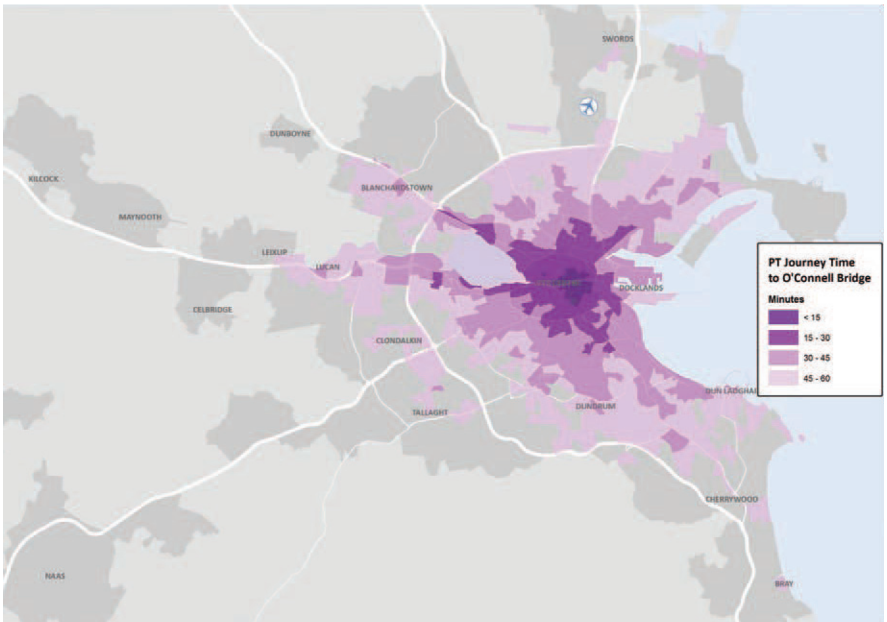



**Figure 7: Travel time by public transport from Dublin Airport to the city centre 2011**
Source: National Transport Authority (2015).

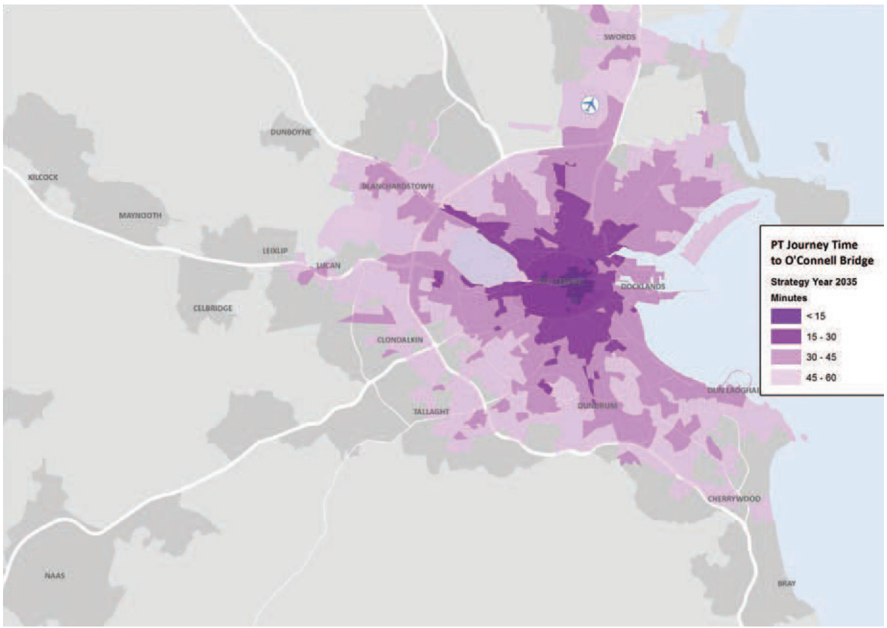



**Figure 8: Travel time by public transport from Dublin Airport to the city centre in 2035 (with strategy)**

Source: National Transport Authority (2015).

- *The Urban Mobility Plan of Vienna* (Vienna City Administration, 2015) highlights the importance of linking the airport with the long-distance rail network. The first proposed stage is to connect the West of Austria via the central railway station of Vienna and then to complement this as quickly as possible by similar services and a direct continuation of the line towards the East.
- In France, planning masterplans or blueprints are produced for each region. The Paris airports are covered by the *Schema Directeur de la Région Île-de-France 2030 (SDRIF)* (DRIEA, 2013). As outlined in D4.1, this proposes the creation of a Grand Paris Express train (using the current metro line 14) linking CDG and Orly via Paris and also calls for the "densification" of populations around railway stations, which will lead to a greater use of public transport in general, and by extension, to the airports (Figure 9).

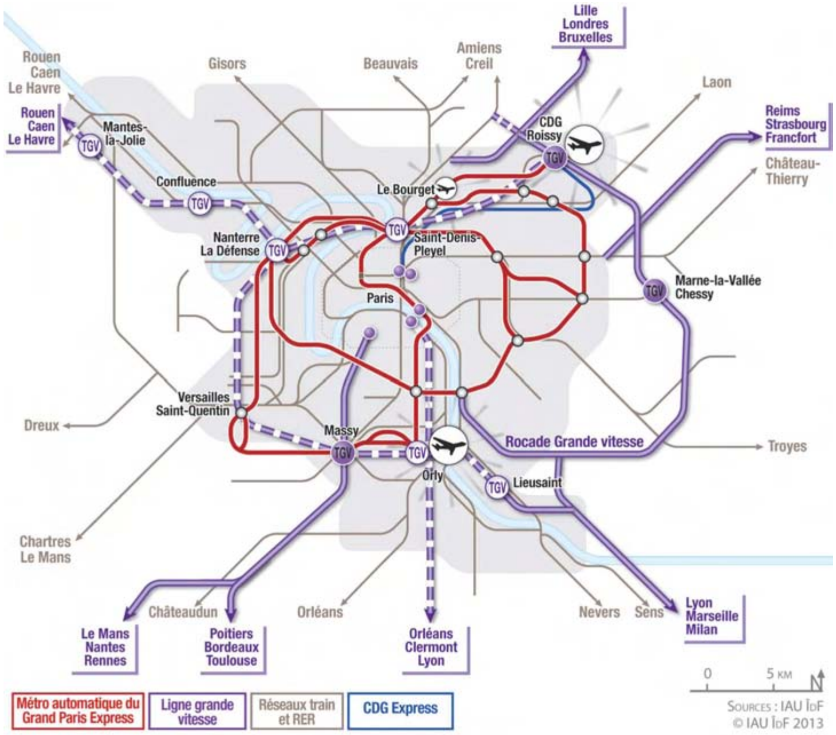



**Figure 9: Surface access proposals for the Paris airports**

Source: DRIEA (2013).

- *The Maltese Transport Master Plan 2025* (Transport Malta, 2016) rather than focusing on surface access infrastructure, comments on the provision of public transport services: *'Improvements to the journey planner, synchronisation of timetables and possible incorporation of multimodal ticketing (to cater for all modes of transport) are required. Together with integrated travel card, the improved timetabling information would provide a better seamless intermodal experience. The peak travel times for the airport do not coincide with the road traffic peak periods. Therefore the public transport operator needs to consider provision of services that coincide with this travel demand. The scheduled bus service at the airport also does not extend long enough into the evening to provide transport for late night flight arrivals (in particular low cost carrier passengers)'*
- In the UK, there is the *National Infrastructure Plan*, since updated by the National Infrastructure Delivery Plan 2016-2021 (Infrastructure and Projects Authority, 2016) where priority projects to improve surface access to airports up until 2020-21 are identified. These cover road improvements (A6 to Manchester Airport; M42 supporting access to Birmingham Airport; M23 serving Gatwick Airport) and improvements to Gatwick Airport's railway station and trains. Table 11 presents the up-to-date details of these priority areas.

**Table 11: Surface access priority projects in the UK**

| Priority | Key projects | Delivery body | Current status | By end of 2020-21 |
|---|---|---|---|---|
| Surface access improvements | A6 to Manchester Airport Relief Road | Stockport Council | In construction | Complete (2017) |
| | M42 Junction 6 | Highways England | Scoping | In construction |
| | M23 Junctions 8 - 10 | Highways England | Planning and consents | Complete (2019-20) |
| | Gatwick Airport rail station | Network Rail | Planning and consents | Complete (2020) |

Source: Infrastructure and Projects Authority (2016).

Key national rail projects affecting airports are Crossrail at Heathrow to be completed by 2019, and the High Speed Rail 2 project (HS2). Phase 1 of HS2 will include a station at Birmingham Airport which is planned to open around 2026, whereas phase 2 will involve a station at Manchester Airport and is planned to open around 2033. Also in the UK, the National Infrastructure Commission was set up by the government in 2015 as an independent body to provide unbiased analysis of long-term infrastructure (including transport) needs. This has the potential to look at national transport networks and airport planning, and so it may help towards providing a more coordinated approach to surface access.

**Government Aviation or Airport Plans**

Surface access is also discussed in some countries in National Aviation Plans or specific airport plans produced by governments:

- *The National Aviation Policy for Ireland* (Department of Transport, Tourism and Sport, 2015) mentions improvements needed for the Swords Corridor and Dublin airport as discussed in the Dublin Transport Plan, but also states that no changes to the public access infrastructure for the other main airports, Cork and Shannon, are planned.
- The *Austrian Aviation Road Map 2020* (Federal Ministry for Transport, Innovation and Technology (BMVIT), 2011) provides an analysis of surface transport to the main airports in Austria (Table 12) and the proposed major improvements (Table 13).

**Table 12: Surface access at Austrian airports**

| Airport | Motorway | Local rail | Regional and long-distance rail | Bus |
|---|---|---|---|---|
| Vienna | ★★★ | ★★★ S7 train, City Airport Train (CAT); CAT not yet extended to Bratislava Airport (BTS) | – – – | ★★★ |
| Salzburg | ★★– Improvement possible | ★– – Transfer at main railway station | – – – | ★★★ |
| Innsbruck | ★– – | | – – – | ★★★ |
| Graz | ★★★ | ★★– Within walking distance | – – – | ★★★ |
| Linz | ★– – | – – – | – – – | ★★★ |
| Klagenfurt | ★★★ | ★– – Within walking distance (long) | – – – | ★★★ |

Key: very good ★★★; good ★★–; fair ★– –; absent – – –.
Note: S7 is a local service, the CAT connects with Wien Mitte railway station but this is not the main station in Vienna.
Source: BMVIT (2011).

**Table 13: Proposed surface access improvements at Austrian airports**

| Measures at the national level: | To be carried out by: | Priority |
|---|---|---|
| Greater involvement of aviation in intermodal transport | bmvit, airports, carriers of traffic, federal states | ★★★★★ |
| **Measures at the EU/international level:** | | |
| Connecting Vienna International Airport to Vienna Central Train Station and/or Bratislava and Budapest | bmvit & ÖBB | ★★★★– |
| Supporting efforts to extend the City Airport Train to Bratislava | ÖBB & VIE | ★★– – – |

Key: highest priority ★★★★★; lowest priority ★– – – –.
Note: bmvit = Federal Ministry for Transport, Innovation and Technology; ÖBB = Austrian Federal Railways; VIE = Vienna Airport.
Source: BMVIT (2011).

- In Denmark, the *Danish Aviation* report (Committee of Danish Aviation, 2012) stated that: *'Accessibility to the airports should … be included in the prioritization of the extension of the transport infrastructure. The opportunities for and the consequences of linking Copenhagen Airport to a north European high-speed network should be explored.'*

- In the UK, the *2013 Aviation Policy Framework*, (Department for Transport, 2013) states that it is developers that should pay the costs of upgrading or enhancing road, rail or other transport networks or services, where there is a need to cope with additional passengers travelling to and from expanded or growing airports. However, if such schemes have wider benefits, the government will, on a case-by-case basis, assess the need for additional public funding. It is also planned that the government will produce an *Airports National Policy Statement* in 2018, confirming its approval for a third runway at Heathrow. This document will help clarify how planning decisions will be made in relation to surface access improvements.
- At Stockholm Arlanda Airport in Sweden (Stockholm Arlanda Airport, 2017), the government has put a cap on carbon dioxide emissions, which is the only airport in the world to have such a cap. This means that emissions from aircraft taking off and landing, from vehicular traffic to and from the airport, from internal vehicular traffic, and from the heating of buildings, may not exceed the level produced in 1990. This plays a key role in surface access initiatives at the airport and is likely to be introduced at other airports in the future.
- *The Schiphol Action Programme* (Ministry of Infrastructure and the Environment/Ministry of Economic Affairs, 2016) in the Netherlands lists a number surface access planned improvements, representing nearly €12 billion up until the end of the 2018 (Table 13). These include:
  - *Agreement of intent for renewal and expansion of multimodal hub station at Schiphol Airport;*
  - *Track expansion on the line running between Schiphol Airport – Amsterdam – Almere – Lelystad;*
  - [Completion] *of high-frequency rail transport around Amsterdam and Schiphol Airport;*
  - *Improvement of the Schiphol Tunnel;*
  - [Completion] *of the ZuidasDok;*
  - *Widening the road connection between Schiphol Airport – Amsterdam – Almere;*
  - *Rerouting the A9 motorway at Badhoevedorp.*

**Table 14: Dutch Government contribution to infrastructure projects around Schiphol Airport**

| Project | Description | Completion | Parties involved |
|---|---|---|---|
| Westtangent | A new HQ PT bus connection between station Sloterdijk and Schiphol Airport | 2019 | SRA, Schiphol Airport, Amsterdam, Haarlemmermeer, NoordHolland |
| Junction Schiphol Zuid | Development of a new bus station | 2017 | SRA,Haarlemmermeer, Aalsmeer, Noord-Holland |
| HQ PT on A9 motorway | A fast, frequent bus connection between Haarlem, Badhoevedorp, Schiphol Airport, Amstelveen and AmsterdamZuid. | 2020 | SRA, Schiphol Airport, Haarlemmermeer, Haarlem, Amstelveen, NoordHolland, Min. of Infrastructure and the Environment |
| HQ PT Schiphol Oost | An open bus lane SchipholOost as a part of the ring line of high-quality buses around Schiphol | 2017 | SRA, Schiphol, Haarlemmermeer, Noord-Holland |
| Junction Schiphol Noord | An energy-neutral bus station with transfer possibilities in all directions | Completed | SRA, Schiphol Airport, Haarlemmermeer, NoordHolland, Ministry of I&E |

Source: Ministry of Infrastructure and the Environment/Ministry of Economic Affairs (2016).

**Policies at an Airport Level**

At a number of airports, the airport operator will cooperate with local transport operators and local authorities, to enhance the quality of the surface access and encourage more public transport usage, often by producing surface access or mobility plans. One example of such cooperation is the Letter of Intent signed by Stockholm Arlanda Airport, public transport providers, the Swedish Road Administration (SRA) and local and regional planning authorities, in September 2008. This Letter of Intent aims at improving public transport connections to the airport and discouraging the use of private cars. It supports a specific Action Programme that includes measures to increase accessibility to the airport; reduce carbon emis-sions from ground transport; and achieve the zero vision for $CO_2$ (from heating, electricity consumption and airport vehicles).

The most widespread use of such cooperation practice is in the UK. As discussed D4.1 (Section 3.5), all main airports establish an airport surface access strategy (ASAS). These cover plans and targets for different aspects of surface access provision and use. For example, Table 15 shows the targets set for passenger public transport use at the London area airports.

**Table 15: Passenger public transport usage targets for London airports**

| Airport | Public transport target |
|---|---|
| Heathrow | Maintain above 40% until 2019 |
| Gatwick | Achieve 40% public transport mode share for air passengers by the time the airport reaches 40 million passengers per annum (mppa)<br>Identify feasible measures to achieve a stretch target of 45% public transport mode share once the 40% target at 40mppa has been achieved |
| Stansted | Maintain at least 50% until 2019 |
| Luton | Increase to 40% by 2017 |

Sources: Heathrow Airport (2014), Gatwick Airport (2011), Stansted Airport (2016), Luton Airport (2011).

This indicates that a share of 40-50% seems to be a reasonable target for a city like London, although the targets for the generally less accessible regional airports are lower (e.g. 15% for East Midlands, Birmingham 37%, Edinburgh 35%, Newcastle 30%).

Norway leads the way in Europe for public transport use at airports. In 2008, the Norwegian airport operator Avinor adopted a goal of reaching the 70% public transport share at Oslo Airport in 2020 – but is likely to have achieved this ahead of schedule in 2015. It claims that it remains on-track to achieve a 75% share by 2030 (Avinor, 2016). It also has challenging targets at some regional airports as well (Table 16).

**Table 16: Passenger public transport usage targets for Norwegian airports**

| Airport | Actual 2014 | Target 2020 | Target 2030 |
|---|---|---|---|
| Oslo | 66% | 70% | 75% |
| Trondheim | 45% | 50% | N/A |
| Bergen | 34% | 40% | N/A |
| Stavanger | 17% | 30% | N/A |

Source: Avinor (2016).

### Environmental restrictions

From an air quality standpoint around airports, the most significant pollutant is $NO_x$ due to emissions below 1000 ft. Whilst there is no specific EU legislation in relation to aviation emissions for $NO_x$, the general EU legislation which limits values for the pollutants, and in particular for $NO_x$, applies around airports and $NO_x$ pollution already has an impact on aviation operations as it might limit the possibilities of future airport expansion. In the future, $NO_x$ pollution could be costed or have permit allocations, as does $CO_2$. Where national policies exist to improve surface access at airports they are driven primarily due to forecast growth in air transport; the desire for more efficient, convenient and quicker accessibility with a better passenger experience; and a need to reduce harmful emissions.

### Corporate policy

Companies' sustainability and reporting trends clearly demonstrate a will to great transparency and a step towards a sustainable economy. According to the KPMG Survey of Corporate Responsibility Reporting 2013 (KPMG, 2013), growth in reporting practices since

1993 has been substantial. Today, the world's major companies disclose their sustainability performance to some extent. As more and more data are gathered, reporting on sustainability impacts can be done more effectively in the future and sustainability goals can be measured more easily. The Global Reporting Initiative (GRI) discovered trends indicating how corporate responsibility will develop in the next decade (GRI, 2015), in summary:

- Companies will be held accountable for their actions;
- Business leaders will take sustainability issues into account more profoundly;
- Technological progress will allow companies to operate in a more integrated way;
- Ethical values, reputation and risk management will play a more important role in companies' decision making;
- Not only will external factors and stakeholder interests drive sustainability efforts, but also company internal strategic thoughts.

Strandberg Consulting found similar and additional trends in their study about the future of corporate social responsibility. In expert interviews they uncovered that increasing social and environmental crises will continue to foster the underpinnings of corporate social responsibility. Stakeholders will have an increasing influence on companies' CSR practices, both through increased dialogue and campaigning. The companies themselves will pull suppliers more and more into their CSR practice. "The future CSR company will require every policy, practice, operation, activity, member of staff, every decision to be measured against CSR criteria" (Strandberg Consulting, 2002). Governments will make the disclosure of corporate social and environmental performance mandatory.

Companies will make their contribution to address the growing social and environmental challenges ahead. They will seek to generate economic, social and environmental benefits.

At the same time, stakeholders will be watching and control whether societal expectations of a sustainable economy are met by judging the companies' efforts towards this aim.

This environmental focus will lead to a higher use of less polluting means of transport to access the airport and hence might increase the required time as environmental factors are considered.

### 3.1.3 Future values

The next two tables bring together the parameters likely to affect the door-to-kerb journey phase (as discussed above), and the expected impact on passengers' future travel time. Time saving impacts that help the four hour D2D target are shown as "–" (multiple instances are better), whilst those that hinder the four hour D2D target are shown as "+" (multiple instances are worse).

Table 17: Expected impact of door-to-kerb parameters per high-level group on 2035 travel time

| Parameters | | 2035 | | |
|---|---|---|---|---|
| | | Model scenario 1: weak supporting changes | Model scenario 2: expected supporting changes | Model scenario 3: strong supporting changes |
| **H1. Traffic / demand** | | | | |
| Door-to-kerb (& kerb-to-door) | **NET IMPACT** | **~0** | + | + + + + |
| | Ageing population | – | – | – |
| | Population growth | + + | + + | + + |
| | Urbanisation | – | – | – |
| | Environmental awareness | ~0 | ~0 | + |
| | Air transport demand | ~0 | ~0 | + + |
| **H2. Market forces / technologies / supply** | | | | |
| Door-to-kerb (& kerb-to-door) | **NET IMPACT** | – | – | – – – – |
| | Higher train frequency | – | – | – |
| | Autonomous vehicles | ~0 | – | – – |
| | High-speed trains | ~0 | ~0 | – |
| **H3. Policy / regulation** | | | | |
| Door-to-kerb (& kerb-to-door) | **NET IMPACT** | + | + | + + + + |
| | Environmental regulation | + | + + | + + |
| | Connecting core airports to rail network | ~0 | – | – |
| | Airports' public transport targets | ~0 | + + | + + |
| | Corporate policies | ~0 | + | + |

Note: – shows time saving; + shows time increase.

**Table 18: Expected impact of door-to-kerb parameters per high-level group on 2050 travel time**

| Parameters | | 2050 | | |
|---|---|---|---|---|
| | | **Model scenario 1:** weak supporting changes | **Model scenario 2:** expected supporting changes | **Model scenario 3:** strong supporting changes |
| **H1. Traffic / demand** | | | | |
| Door-to-kerb (& kerb-to-door) | **NET IMPACT** | **~0** | + | + + + + + |
| | Ageing population | – – | – – | – – |
| | Population growth | + + + | + + + | + + + |
| | Urbanisation | – – | – – | – – |
| | Environmental awareness | ~0 | + | + + |
| | Air transport demand | ~0 | ~0 | + + + |
| **H2. Market forces / technologies / supply** | | | | |
| Door-to-kerb (& kerb-to-door) | **NET IMPACT** | – – – | – – – – – | – – – – – – |
| | Higher train frequency | – – | – – | – – |
| | Autonomous vehicles | – | – – | – – – |
| | High-speed trains | ~0 | – | – |
| **H3. Policy / regulation** | | | | |
| Door-to-kerb (& kerb-to-door) | **NET IMPACT** | + | + + + + | + + + + + |
| | Environmental regulation | + + | + + + | + + + |
| | Connecting core airports to rail network | – | – – | – – – |
| | Airports' public transport targets | + | + + | + + + |
| | Corporate policies | + | + | + + |

Note: – shows time saving; + shows time increase.

## 3.2 Kerb-to-gate

### 3.2.1 Current values

Table 19 gives an overview of the available current kerb-to-gate/gate-to-kerb data required by each airport archetype. Refer to Table 28 in Section 5 for a summary of available data for all journey phases.

**Table 19: Overview of the availability of current kerb-to-gate data**

| Airport archetype | Kerb-to-gate time (data availability rating[1]) | Gate-to-kerb time (data availability rating[1]) |
|---|---|---|
| (1) Main hub | Time to terminal door: range of values (3)<br>Walking time in airport: range of values (3)<br>Check-in time: average value (6)<br>Bag-drop time: average value (6)<br>Security time: average value (6) | Immigration time: average value (6)<br>Bag-reclaim time: average value (6)<br>Customs time: (7)<br>Time from terminal door: *derived from K2G* |
| (2) Secondary hub | Time to terminal door: range of values (3)<br>Walking time in airport: range of values (3)<br>Check-in time: average value (6)<br>Bag-drop time: average value (6)<br>Security time: average value (6) | Immigration time: average value (6)<br>Bag-reclaim time: average value (6)<br>Customs time: (7)<br>Time from terminal door: *derived from K2G* |
| (3) Large/medium | Time to terminal door: (7)<br>Walking time in airport: range of values (7)<br>Check-in time: average value (6)<br>Bag-drop time: average value (6)<br>Security time: average values (5) | Immigration time: average value (6)<br>Bag-reclaim time: average value (6)<br>Customs time: (7)<br>Time from terminal door: (7) |
| (4) National/regional | Time to terminal door: (7)<br>Walking time in airport: range of values (7)<br>Check-in time: average value (7)<br>Bag-drop time: average value (7)<br>Security time: average value (6) | Immigration time: average value (7)<br>Bag-reclaim time: average value (7)<br>Customs time: (7)<br>Time from terminal door: (7) |

[1] Data availability rating: the *lower* the score, the *more* data that are available (refer to Section 3).

### 3.2.2 Future impacts

#### *3.2.2.1 H1 traffic/demand*

The kerb-to-gate time is likely to be influenced more by the type of passenger than by the number of passengers. Indeed, airports are usually congested because of the limited runway capacities, rather than terminal capacity. As a consequence, the main choices available to passengers with respect to check-in procedures, for instance, will determine the gain or loss in travel time.

An ageing population will likely imply a smaller use of the 'self options', e.g. digital self-checking. Older people rely more on known procedures involving human interaction rather than by machine, which will lead to longer times in the airport overall.

The population growth itself is likely to have a minor effect on the kerb-to-gate time alone. Indeed, airports are primarily congested because of their limited runway capacity, which over the years has naturally led to an increase in the average size of the aircraft without affecting the level of congestion at the airport. For the same reason, air transport demand itself has only a marginal effect.

No other higher-level factor listed in Section 4.2.2.1 can be linked to the increase or decrease of the travel time on this leg.

#### *3.2.2.2 H2 market forces/technologies/supply*

The 2050+ Airport project (FP7) developed three different concepts to support the development of airports in 2050 and beyond. Of these, the time-efficient (TE) airport concept is most relevant when considering the four hour door-to-door goal, with its aim of improving time efficiency in all aspects of airport operations (i.e. not just kerb-to-gate).

Definition of the time-efficient airport concept (2050+ Airport, 2014):

> *The "Time-Efficient airport" is the airport that has been designed and is operated and managed in such a way that the mobility value is maximized for both passenger and aircraft, through efficient and effective air transport operations. Based on new forthcoming technology it aims to make sure that the passenger's and the aircraft's throughput time through the airport is minimized and that seamless intermodality is guaranteed. To do this the airport applies intelligent, collaborative, dynamic, and automated systems capable of reacting to the daily needs of its stakeholders.*

Many technologies are being considered by airports to make the passenger experience at the airport better. Several specific technologies are in competition, but they all tend to minimise the throughput time of passengers by enabling the following changes:

- Quicker check-in;
- Quicker bag drop-off;
- Quicker document check;
- Quicker boarding.

In particular, in many cases, self-executed tasks are thought to be a good alternative to staff-executed ones (IATA, 2016a). Findings from an industry supplier go further, stating that once passengers convert to self-service technology, few wish to return to using agents again and would rather switch to another technology instead (SITA, 2017). As a consequence, most of the processes that the passenger has to go through will be 'self-tasks' in the future, such as self check-in, self bag drop, self boarding, and self passport check. These tasks are expected to enhance the satisfaction of the passenger overall and reduce the queuing time for most of these processes. For instance, self bag dropping is expected to raise the number of bags processed from 24 per hour to 60 per hour when fully implemented.

Many technologies are also oriented towards a better management of uncertainties at the airport. One of the main challenges today is to predict the size of the queue with a sufficient time horizon so more staff can be deployed in time to cope with higher demand. Different methods are planned to achieve this, ranging from big data analysis (at Heathrow to predict passenger flows almost in real time) to real time passenger tracking thanks to wifi, RFIDs (Sabre 2015), beacons (e.g. at Miami airport, see Jenkins 2015), facial recognition (e.g. at Luton airport, see Thompson 2015), etc.

Another technology envisioned is some kind of 'single token identification', where a passenger is uniquely identified once (e.g. using a biometric identifier) and does not need to be identified again after that – intervention would only be required if a deviation is detected. This would reduce the number of steps that the passengers go through and hence reduce the total processing time. An important development towards seamless travel.

The goal of the PASSME project (Horizon 2020) is to reduce passengers' travel time by at least one hour (K2G/G2K), in part by integrating information between all airport stakeholders and improving the airport experience. Such information-based initiatives are consistent with IATA's *Simplifying the Business* (StB) programme which aims to transform the entire passenger journey through the implementation of innovative solutions. Current StB projects include: *New Distribution Capability* that will enhance the capability of communications between airlines, travel agents and any third party; *Travel Communications* will provide consistent and accurate travel communication to passengers throughout the journey; and *Customer Contact Information* will enable passengers to be reached in the event of disruption with any relevant information pertaining to their journey (IATA, 2016b).

Another important innovation is the concept of smart ticketing. No complete and functional implementation exists yet to our knowledge, but the idea is to ensure the point-to-point travel of the passengers via multi-modal automatic reaccommodations. Based on information about the position of the passenger and the issues foreseen during the travel, an algorithm could suggest reaccommodation for a passenger without extra fee. This type of service is currently a niche market, with fee-based mobile applications (such as 'Freebird' that covers domestic US flights) providing reaccommodation options onto any airline, directly to passengers during disruption (SITA, 2017). This would allow us to reduce a major contribution to the time travel: buffer times, taken usually by passenger in order to prevent the loss of a plane ticket because of a prior uncertain travel time to the airport. In the model, the buffer times are counted as K2G times, since they are usually spent at the airport.

Finally, different technologies are considered, linked to augmented reality, virtual assistant etc. (Sabre 2015). These technologies are aiming at having a better passenger experience, but are likely to have only a marginal impact on the travel times itself.

#### *3.2.2.3 H3 policy/regulation*

Regulation 261/2004 establishes the minimum rights for passengers when they are denied boarding, their flight is cancelled or delayed. This includes right of care and right to compensation (European Commission, 2004). Currently, the European Commission is adopting interpretative guidelines in order to provide guidance to citizens and airlines on current passengers' rights (Regulation 261/2004) until formal legislative amendments become available. It will also evaluate how to promote cooperation between National Enforcement Bodies and authorities (European Commission, 2015). In March 2013, a memo was released by the Commission (European Commission, 2013) detailing the key proposed changes to clarify legal grey areas and introducing new rights. In February 2014, the following proposed strengthening (*inter alia*) of air passenger rights passed its first reading in the European Parliament (European Commission, 2014):

- Right to care: introduction of a right to care for passengers after a delay of two hours, for all flights irrespective of distance (thereby removing the current dependency on flight distance);
- Re-routing: ensuring passengers have a right to be re-routed by another airline or transport mode in case of cancellation when the carrier cannot re-route on its own services;
- Connecting flights: clarifying that rights to assistance and compensation apply if connecting flights are missed because the previous flight was delayed by at least 90 minutes.

The European Parliament's proposals also go further than those proposed by the Commission in strengthening air passenger rights (European Commission, 2014):

- Compensation for delays (short and medium flights): the Parliament proposes a three hour delay threshold for compensation. In contrast, the Commission considers a five hour threshold to be in passengers' best interests, with a longer delay threshold reducing the financial incentive on airlines to cancel delayed flights to avoid paying compensation, and instead make every effort to repair technical problems and operate flights;
- Extraordinary circumstances: the Parliament backs the Commission's proposal to clearly define extraordinary circumstances (e.g. strikes, storms and operational problems) which are outside an airline's control, so excluding any compensation obligation. However, unlike the Commission's proposal, the Parliament proposes that technical faults can almost never be exempt.

The appetite for increasing support of the passenger through regulation is clear. In the future, it is quite possible that paradigm changes in regulatory provision will be introduced to further support passenger mobility and reduce D2D times. These could be within the framework of what is currently known as Regulation 261, or as entirely new, complementary instruments. Possible evolutions of passenger provision regulations include:

- Passengers entitled to compensation being automatically compensated; and
- Load factors maintained significantly below 100% on key/connecting/trunk routes to reserve some capacity for rebooking passengers who miss flights/connections.

The latter represents a 'social' capacity and resilience provision supporting Flightpath 2050 ambitions through new regulatory paradigms, for example for passengers who arrive late at the airport (due to a public transport issue) and miss their flight, or miss a flight connection due to a delayed first flight in a multi-leg itinerary. The former would be intended to encourage many passengers not to allow long buffer (wait) times at airports due to fears of missing flights, and could thus substantially reduce D2D times. Note that some passengers may still prefer to spend time at the airport (which raises questions regarding utility metrics, to be addressed in WP5) and such a social capacity scheme would come at a cost, which would need to be borne by the state(s) (and which could be estimated to a reasonable approximation from airline sales data). This also links to smart, integrated ticketing, as discussed in Section 3.2.2.2. Quantitative benefits of these effects, including the impact of social capacity, could be estimated from the DATASET2050 core (G2G) model.

### 3.2.3 Future values

The next two tables bring together the parameters likely to affect the kerb-to-gate journey phase (as discussed above), and the expected impact on passengers' future travel time. Time saving impacts that help the four hour D2D target are shown as "–" (multiple instances are better), whilst those that hinder the four hour D2D target are shown as "+" (multiple instances are worse).

**Table 20: Expected impact of kerb-to-gate parameters per high-level group on 2035 travel time**

| Parameters | | 2035 | | |
|---|---|---|---|---|
| | | Model scenario 1: weak supporting changes | Model scenario 2: expected supporting changes | Model scenario 3: strong supporting changes |
| **H1. Traffic / demand** | | | | |
| Kerb-to-gate (& gate-to-kerb) | **NET IMPACT** | + | + | + |
| | Ageing population | + | + | + |
| | Population growth | ~0 | ~0 | ~0 |
| | Air transport demand | ~0 | ~0 | ~0 |
| **H2. Market forces / technologies / supply** | | | | |
| Kerb-to-gate (& gate-to-kerb) | **NET IMPACT** | ---- | ----- | ------ |
| | Self check-in;<br>Self bag-drop;<br>Self boarding | – | – | – |
| | Token-based identification;<br>Anonymised facial recognition | – | – | – |
| | Digital Wayfinding;<br>Mobile tracking/proximity sensing | – | – | – |
| | Service robotics, augmented reality, virtual assistant, geofencing, etc. | ~0 | ~0 | ~0 |
| | Smart ticketing | – | -- | --- |
| **H3. Policy / regulation** | | | | |
| Kerb-to-gate (& gate-to-kerb) | **NET IMPACT** | **~0** | – | – |
| | Passengers' rights | ~0 | – | – |

Note: – shows time saving; + shows time increase.

Table 21: Expected impact of kerb-to-gate parameters per high-level group on 2050 travel time

| Parameters | | 2050 | | |
|---|---|---|---|---|
| | | Model scenario 1: weak supporting changes | Model scenario 2: expected supporting changes | Model scenario 3: strong supporting changes |
| **H1. Traffic / demand** | | | | |
| Kerb-to-gate (& gate-to-kerb) | **NET IMPACT** | ++++ | ++++ | ++++ |
| | Ageing population | ++ | ++ | ++ |
| | Population growth | + | + | + |
| | Air transport demand | + | + | + |
| **H2. Market forces / technologies / supply** | | | | |
| Kerb-to-gate (& gate-to-kerb) | **NET IMPACT** | ----- | ------ | ------- |
| | Self check-in; Self bag-drop; Self boarding | - | - | - |
| | Token-based identification; Anonymised facial recognition | - | - | - |
| | Digital Wayfinding; Mobile tracking/proximity sensing | - | - | - |
| | Service robotics, augmented reality, virtual assistant, geofencing, etc. | ~0 | ~0 | ~0 |
| | Smart ticketing | -- | --- | ---- |
| **H3. Policy / regulation** | | | | |
| Kerb-to-gate (& gate-to-kerb) | **NET IMPACT** | - | - | - |
| | Passengers' rights | - | - | - |

Note: – shows time saving; + shows time increase.

## 3.3 Gate-to-gate

### 3.3.1 Current values

Table 22 gives an overview of the available current gate-to-gate data required by each airport archetype. Refer to Table 28 in Section 5 for a summary of available data for all journey phases.

**Table 22: Overview of the availability of current gate-to-gate data**

| Airport archetype | Gate-to-gate time<br>(data availability rating[1]) |
|---|---|
| (1) Main hub | Boarding time: *generic*<br>Transfer time: range of values (5)<br>Minimum connecting time: range of values (3)<br>De-boarding time: *generic* |
| (2) Secondary hub | Boarding time: *generic*<br>Transfer time: range of values (5)<br>Minimum connecting time: range of values (3)<br>De-boarding time: *generic* |
| (3) Large/medium | Boarding time: *generic*<br>Transfer time: range of values (5)<br>Minimum connecting time: range of values (3)<br>De-boarding time: *generic* |
| (4) National/regional | Boarding time: *generic*<br>Transfer time: range of values (5)<br>Minimum connecting time: range of values (3)<br>De-boarding time: *generic* |

[1] Data availability rating: the *lower* the score, the *more* data that are available (refer to Section 3).

### 3.3.2 Future impacts

#### *3.3.2.1 H1 traffic/demand*

Two key gate-to-gate time factors include (i) airport congestion and, (ii) the propensity of passengers to take point-to-point (i.e. direct) flights rather than connecting ones. The former is tightly linked to the volume of passengers whereas the latter is more affected by the composition of the model.

An ageing population means that quicker and simpler itineraries are more likely to be favoured. As a consequence, more point-to-point travel should be preferred by passengers and the total travel time should decrease.

Population growth and air transport demand go in the same direction once again. Both open the possibility to future over-congested airports due to limited runway capacities – the delays incurred can be significant, thus increasing travel time.

Environmental awareness might also have an impact on the gate-to-gate time, due to passengers becoming more likely to choose quicker/smaller itineraries, in particular point-to-point. This will tend to decrease the gate-to-gate travelling time by eliminating connections.

### *3.3.2.2 H2 market forces/technologies/supply*

**SESAR targets**

The gate-to-gate journey phase is already quite efficient time-wise, and the expected improvements are on the whole rather small compared to the gains expected during the D2K and K2G legs. However, the total gate-to-gate time comprising connections could be compressed by a more efficient, point-to-point travel paradigm similar to what 'low-cost' companies are doing today.

Many of the future gains of the pure gate-to-gate journey can be forecast thanks to the work done by SESAR which collects in high-level packages some of the most important technological changes for the future. SESAR is indeed organised in several operational workpackages for which targets have been set for different KPIs coming from ICAO. We base our forecast of the potential gains on these targets, which are the best quantitative guess for their impact. SESAR in the past has set three series of targets for 'time-based operations', 'trajectory-based operations', and 'performance-based operations', initially thought to be reached within three steps – three successive time horizons. The steps have now disappeared from the most recent edition of the Master Plan (Edition 3), and have been replaced by some high-level targets for 2035. One can check that these new targets are roughly consistent with the former Step 3 targets.

As a consequence, we consider that the most optimistic scenario for 2035 (strong supporting changes) should reach these Step 3 targets. Since Step 1 targets are likely to be reached by 2020 in any case, we chose to consider that in the pessimistic scenario, Step 2 targets will have been reached. For the medium scenario, we made a linear interpolation between the targets. Regarding 2050, no targets have been set to the best of our knowledge, so we rely on extrapolations. These extrapolations are described hereafter, but first the relevant KPIs for this study are briefly described.

We insist on the fact that in the following we use the later steps only in relation to the targets set at the time, which are only used to estimate the SESAR Operational Packages on the system. We are fully aware that the targets themselves are obsolete and should not be used otherwise.

**SESAR KPIs**

Over the years, SESAR have considered several KPIs relating to the total time of travel, and we are interested in three of them. The first one is relatively new and has been described in the latest edition of the Master Plan as "flight time per flight (min/flight)". We chose to consider this "flight time" as an initial planned flight time, since delays are captured in other KPIs. The high-level target for 2035 is a reduction by 5%-10% (w.r.t 2012). Interestingly, this target is close to the target for the fuel reduction, 3%-6%, which is normal since the latter metric is mainly linked to the 'trajectory efficiency' metric – measuring how close the trajectory is from the corresponding grand circle. It is likely that the "flight time" has been introduced to decouple the geometrical gain from the fuel burn per kilometre in the old metric. As a consequence, we assume here that the “flight time” can be computed based on the “fuel efficiency” one by computing the ratio between the corresponding high-level targets (10% and 6% respectively) and applying it to all the intermediate fuel efficiency gains. Since the targets for the fuel efficiency are known per step per Operational Package, we have access to a pretty good estimation of the flight time on the same basis by just dividing each target by this ratio.

The second relevant metric here is punctuality, i.e. the average of the delay per flight. There were no ‘step targets’ for this metric, but there is a high-level target for it in the latest edition of the Master Plan, which is 10-30%. Moreover, we also know that some validation exercises have estimated the gain in punctuality for Step 1, which is 4.85%. This gain is entirely provided by one Operational Package, number 5, and we have thus considered that all the gains for 2035 would come from this package too.

Finally, the last relevant metric is unpredictability, defined by SESAR as the standard deviation of the delay. This metric has ‘step targets’, which make it easy to compute in theory, but we decided to base our projections on the validation exercises for Step 1 instead, for reasons explained below.

In the summary tables below, we have included the three metrics, with “planned travel time” corresponding to ‘flight time’, “decreased tactical delay” to ‘punctuality’, and “decreased variability” to ‘unpredictability’.

**Inter/extrapolation of targets**

For our projections, we need some interpolation and extrapolation of the above targets to find out the targets in the different scenarios:

- Pessimistic for 2035, roughly corresponding to the latest Step 2;
- medium for 2035, roughly between optimistic and pessimistic;
- optimistic for 2035, roughly corresponding to the latest Step 3;
- pessimistic for 2050, roughly corresponding to the latest Step 3;
- medium for 2050, roughly corresponding to a ‘Step 4’;
- optimistic for 2050, roughly corresponding to a ‘Step 5’;

We begin by considering the flight time. If the metric was a synonym of ‘trajectory efficiency’, there would be a hard physical constraint on how much one can gain from it. Indeed, evidence suggests that the trajectory efficiency is around 95% already in Europe for the en-route part (number from 2010). This means that roughly 5% could be gained in terms of flight time. However, it is clear that the trajectory efficiency is just one part of the flight time, as we explained above. Other types of gains can be made elsewhere, probably during taxi-time (which is included in the metric as far as we understand). As a consequence, we decided to use linear inter/extrapolation for have the missing values (2nd, 4th, 5th, and 6th bullets above).

For punctuality and variability, linear extrapolation is not so good. Indeed, a linear law is unlikely to happen since an asymptotic approach to 0 zero delay with 0 variability is expected on the very long term. Instead of a linear law, we chose to consider that a geometrical law is much more likely, i.e. a reduction by a **constant factor over a constant period**. For punctuality, we have only two points to be extrapolated from (-4.85% for Step 1 and -30% for Step 3). So we use the ratio between these two targets as the geometrical reason and use it to inter/extrapolate to the other time horizons.

For variability, we have in theory more data since 'step targets' have been set for this metric. However, the target evolution set by SESAR is very linear, with a reduction of 96% of the variability for Step 3 (64% for Step 2). We chose to consider this target as unrealistically optimistic, and used a geometrical law instead. As a result, we use the ratio between the validation exercise for Step 1 (reduction of 38.76%) and the gain in 2012 with respect to the 2005 baseline, 3.34%. Note that the fact that the target for Step 1 (33.54%) was underestimated is perfectly in line with the application of a geometrical law with respect to an arithmetic one (slower at the beginning). The new target for Step 3 is then a reduction of 61%, which is more realistic but probably pessimistic. The long-term target for 2050 with this law is -90%, which is again probably quite pessimistic given the initial target of -96% (by 2035) from SESAR.

**Operational changes and their qualitative consequences**

In the following sub-section we describe the main market forces and how they impact on the travel time.

To start with, free-routing is probably one of the most important operational changes and is already partially implemented in some airspaces (e.g. Portuguese airspace). The direct effect of free-routing is that these flights can fly a direct route, thus shortening their trajectory instead of going through a series of pre-defined waypoints. As a consequence, the travel time is shorter. However this effect is quite small, since trajectories are already very efficient – 95% of efficiency in average in Europe, i.e. the trajectories can be shortened by a maximum of around 5%. More generally, business trajectories are expected to increase the cost efficiency of the airline, but only slightly improve travel time.

Another improvement at several airports planned for the near future is the use of Time-Based Operations (TBO). Such operations consist of using a fixed time between flights taking-off or landing instead of a fixed distance. This allows a higher throughput at the airport, especially when there is a strong head wind, for example, the introduction of time-based separation at London Heathrow has allowed on average an additional 2.9 aircraft per hour to land during strong winds (Shand, 2016). This additional throughput is important for congested airports as this will decrease the waiting time of some of the flights which cannot land because of a queue.

The two previous paragraphs deal with improvements included in the packages 02 and 03 from SESAR. The other packages of SESAR are also of interest. Operational Package 01 plans the implementation of several improvements related to the airport. Most of them are linked to safety, so the time of travel will be not explicitly modified. Operational Package 04 deals with synchronisation throughout the ATM system and more specifically between airports and air controllers. This workpackage is expected to have a major impact in terms of improved predictability but the impact on the average travel time will be minor. Finally, SESAR Operational Package number 05 collects all the improvement related to true integrated and collaborative management of the flights across stakeholders. It includes user prioritisation, airport demand and supply balancing etc. This last point in particular is expected to yield an improvement of the travel time, since taxi times and queuing times would be reduced.

Concerning the airports more specifically, reducing taxi time is another way of reducing the gate-to-gate travel time. Several technologies, some of which are collected under the term *Advanced Surface Movement Guidance and Control System* (A-SMGCS) – including mostly in SESAR Operational Package 04 – seek to improve the tracking of the movements of aircraft on the ground. Possible safety hazards would also be detected by the same technologies, leading to a potential decrease in the attention required by controllers to monitor individual aircraft. This would lead in turn to faster and safer taxi times. Another recent initiative is electric taxiing whilst the aircraft engines are switched off, either through using an electric motor fixed to the aircraft's nosewheel (e.g. WheelTug) or by attaching an electric tug (e.g. TaxiBot), which not only saves fuel, but should reduce delays triggered by foreign object debris ingested by engines.

There is also currently a huge effort dedicated to the improvement of the turnaround times by using an envisioned 'pit-stop' concept (IATA, 2011). The aircraft would be planned very little time on the ground at each iteration, with clearance for the whole journey, 'pit-to-pit'. This is foreseen to allow the aircraft to stay on the ground for 30 minutes maximum, even for the largest types, with aircraft taxiing to the pit stop area rather than the traditional gate. Improving the time efficiency of the turnaround process was one of the aims of the INTERACTION project (FP7), for example through integrating information from different airport processes within the same system, though quantifiable time savings have yet to be published.

Other more generic improvements are expected before 2035 maybe, and before 2050 for sure. Among them, machine learning techniques like deep learning are expected to help the airlines manage their aircraft and the network manager manage the airlines. The real-time implementation of these techniques will specifically help to reduce tactical delays triggered by suboptimal decisions from the airlines and the network manager. Reduced connection times are also expected through the combination of different factors, including machine learning, higher frequency services, user prioritisation, etc. Connection times are probably one of the low hanging fruits for the improvements of the G2G time, since their share in the total travel time is very sizeable.

However, one of the major factors for the G2G time will in fact be the prominent airline business model in the future. Indeed, since 'traditional' companies tend be hub-based, travelling with them usually imply a connection. The 'low-cost' companies on the other hand tend to have a point-to-point business model and connections are rarely needed when travelling with them. As a result, the total G2G time is very different for these two types of companies and the possible changes of business model will have a major impact on the average travel time in Europe. In addition, shifting towards a more point-to-point model renders obsolete improvements in the connection time. This, combined to the fact that point-to-point travel can lead to major improvement of the travel time, leads us to conclude that this should be the highest priority when it comes to the total travel time – or at least for the G2G time.

Finally, we also include high-speed trains for consideration here. Indeed, as highlighted in Section 4.2.3.1, high-speed trains tend to decrease the demand for short-haul flights, which could lead to an increased share of medium-haul and long-haul flights.

#### *3.3.2.3 H3 policy/regulation*

The same minimum passenger rights established by Regulation 261/2004 discussed in Section 3.2 (kerb-to-gate) also apply during the gate-to-gate phase for connecting passengers. For example as mentioned, in February 2014 the proposed strengthening of air passenger rights by the European Parliament included clarification that rights to assistance and compensation apply if connecting flights are missed due to the previous flight being delayed by at least 90 minutes (European Commission, 2014).

Future increased support of the passenger through regulation is likely, either through Regulation 261, or as new complementary instruments. One of a number of possible evolutions could include a provision to maintain load factors significantly below 100% on key/connecting/trunk routes to reserve some capacity for rebooking passengers who miss their onward connections, thereby reducing excess wait times at connecting airports.

**Environmental restrictions**

In terms of $CO_2$ emissions, a decision has yet to be taken on how ICAO's new Global Market-based Measure scheme (CORSIA) will replace the European Trading Scheme (EU-ETS). A pilot phase of CORSIA is due to start in 2021, however by 2027 the second (full) phase of CORSIA would apply to all States. Aviation's non-$CO_2$ climate impacts (e.g. contrail formation and en-route $NO_x$ emissions) are likely to be better understood in the near future. As a consequence, technical, operational and regulatory measures to control and limit their production may be introduced (EUROCONTROL, 2013a).

### 3.3.3 Future values

The next two tables bring together the parameters likely to affect the gate-to-gate journey phase (as discussed above), and the expected impact on passengers' future travel time. Time saving impacts that help the four hour D2D target are shown as "–" (multiple instances are better), whilst those that hinder the four hour D2D target are shown as "+" (multiple instances are worse).

**Table 23: Expected impact of gate-to-gate parameters per high-level group on 2035 travel time**

| **Parameters** | | **2035** | | |
|---|---|---|---|---|
| | | **Model scenario 1: weak supporting changes** | **Model scenario 2: expected supporting changes** | **Model scenario 3: strong supporting changes** |
| **H1. Traffic / demand** | | | | |
| Gate-to-gate | **NET IMPACT** | + | + | + |
| | Ageing population | – | – | – |
| | Population growth | + + | + + | + + |
| | Environmental awareness | ~0 | – | – – |
| | Air transport demand | ~0 | + | + + |
| **H2. Market forces / technologies / supply** | | | | |
| Gate-to-gate | **NET IMPACT** | – – – –<br>-9.4% (-7.5min) < –<br>(decreased planned travel time)<br>-19% (-1.9min) < –<br>(decreased tactical delay)<br>-61%<br>(decreased variability) | – – – – –<br>-12% (-9min) < –<br>(decreased planned travel time)<br>-25% (-2.5min) < –<br>(decreased tactical delay)<br>-68%<br>(decreased variability) | – – – – – – –<br>-14% (-11min) < –<br>(decreased planned travel time)<br>-31% (-3min) < –<br>(decreased tactical delay)<br>-75%<br>(decreased variability) |
| | SESAR Operational Package 01 | -0.93%<br>(decreased planned travel time)<br>-6.1%<br>(decreased variability) | -1.16%<br>(decreased planned travel time)<br>-6.8%<br>(decreased variability) | -1.39%<br>(decreased planned travel time)<br>-7.5%<br>(decreased variability) |
| | SESAR Operational Packages 02 and 03 (includes TBO, 4D trajectories, etc) | -5%<br>(decreased planned travel time)<br>-19%<br>(decreased variability) | -6.3%<br>(decreased planned travel time)<br>-21%<br>(decreased variability) | -7.6%<br>(decreased planned travel time)<br>-23%<br>(decreased variability) |
| | SESAR Operational Package 04 | -2%<br>(decreased planned travel time)<br>-25%<br>(decreased variability) | -2.5%<br>(decreased planned travel time)<br>-28%<br>(decreased variability) | -3.1%<br>(decreased planned travel time)<br>-31%<br>(decreased variability) |
| | SESAR Operational Package 05 | -1.1%<br>(decreased planned travel time)<br>-19%<br>(decreased tactical delay)<br>-10%<br>(decreased variability) | -1.3%<br>(decreased planned travel time)<br>-25%<br>(decreased tactical delay)<br>-12%<br>(decreased variability) | -1.6%<br>(decreased planned travel time)<br>-31%<br>(decreased tactical delay)<br>-13%<br>(decreased variability) |
| | SESAR ENB02 | -0.37%<br>(decreased planned travel time)<br>-1%<br>(decreased variability) | -0.47%<br>(decreased planned travel time)<br>-1.1%<br>(decreased variability) | -0.56%<br>(decreased planned travel time)<br>-1.3%<br>(decreased variability) |
| | Machine learning and deep learning | – | – | – |

| Parameters | | 2035 | | |
|---|---|---|---|---|
| | | Model scenario 1: weak supporting changes | Model scenario 2: expected supporting changes | Model scenario 3: strong supporting changes |
| | Airlines models (hub-and-spoke vs point-to-point) | – –<br>~0.5<br>(decreased planned travel time) | – – –<br>~ - 0.75 hour<br>(decreased planned travel time) | – – – –<br>~ - 1 hour<br>(decreased planned travel time) |
| | Enhanced connection times | –<br>~ - 0.25 hour<br>(decreased planned travel time)<br>(not cumulative with airlines models) | – –<br>~ - 0.5 hour<br>(decreased planned travel time)<br>(not cumulative with airlines models) | – – –<br>~ - 0.75 hour<br>(decreased planned travel time)<br>(not cumulative with airlines models) |
| | 'Pit stop' | –<br>(decreased planned travel time) | – –<br>(decreased planned travel time) | – – –<br>(decreased planned travel time) |
| | High-speed trains | ~0 | + | + |
| **H3. Policy / regulation** | | | | |
| Gate-to-gate | **NET IMPACT** | – – | – – | – – – – |
| | Single European Sky integration | – | – | – – |
| | Passengers' compensation | – | – | – – |

Note: – shows time saving; + shows time increase.
Impact colour coding:

- Based on KPIs target, division in the subpackages is extrapolated;
- Interpolated through average between Step 2 and Step 3;
- Modified with broader flight time reduction target;
- From validation exercises;
- Linear extrapolation using validation exercise and high-level target.

**Table 24: Expected impact of gate-to-gate parameters per high-level group on 2050 travel time**

| Parameters | | 2050 | | |
|---|---|---|---|---|
| | | Model scenario 1: weak supporting changes | Model scenario 2: expected supporting changes | Model scenario 3: strong supporting changes |
| **H1. Traffic / demand** | | | | |
| Gate-to-gate | **NET IMPACT** | + | + | + |
| | Ageing population | - - | - - | - - |
| | Population growth | + + + | + + + | + + + |
| | Environmental awareness | - | - - | - - - |
| | Air transport demand | + | + + | + + + |
| **H2. Market forces / technologies / supply** | | | | |
| Gate-to-gate | **NET IMPACT** | - - - - - - -<br>-14% (-11min) < -<br>(decreased planned travel time)<br>-31% (-3min) < -<br>(decreased tactical delay)<br>-75%<br>(decreased variability) | - - - - - - -<br>-19% (-15min) < -<br>(decreased planned travel time)<br>-41% (-4min) < -<br>(decreased tactical delay)<br>-84%<br>(decreased variability) | - - - - - - - - -<br>-23% (-18min) ~ -<br>(decreased planned travel time)<br>-49% (-5min) < -<br>(decreased tactical delay)<br>-90%<br>(decreased variability) |
| | SESAR Operational Package 01 | -1.4%<br>(decreased planned travel time)<br>-7.4%<br>(decreased variability) | -1.8%<br>(decreased planned travel time)<br>-8.3%<br>(decreased variability) | -2.2%<br>(decreased planned travel time)<br>-8.8%<br>(decreased variability) |
| | SESAR Operational Packages 02 and 03 (includes TBO, 4D trajectories, etc) | -7.6%<br>(decreased planned travel time)<br>-23%<br>(decreased variability) | -10%<br>(decreased planned travel time)<br>-26%<br>(decreased variability) | -12%<br>(decreased planned travel time)<br>-28%<br>(decreased variability) |
| | SESAR Operational Package 04 | -3.1%<br>(decreased planned travel time)<br>-31%<br>(decreased variability) | -4%<br>(decreased planned travel time)<br>-35%<br>(decreased variability) | -4.9%<br>(decreased planned travel time)<br>-37%<br>(decreased variability) |
| | SESAR Operational Package 05 | -1.6%<br>(decreased planned travel time)<br>-31%<br>(decreased tactical delay)<br>-13%<br>(decreased variability) | -2.1%<br>(decreased planned travel time)<br>-41%<br>(decreased tactical delay)<br>-14%<br>(decreased variability) | -2.6%<br>(decreased planned travel time)<br>-49%<br>(decreased tactical delay)<br>-15%<br>(decreased variability) |
| | SESAR ENB02 | -0.56%<br>(decreased planned travel time)<br>-1.3%<br>(decreased variability) | -0.73%<br>(decreased planned travel time)<br>-1.4%<br>(decreased variability) | -0.9%<br>(decreased planned travel time)<br>-1.5%<br>(decreased variability) |
| | Machine learning and deep learning | - | - | - - |

| Parameters | | 2050 | | |
|---|---|---|---|---|
| | | Model scenario 1: weak supporting changes | Model scenario 2: expected supporting changes | Model scenario 3: strong supporting changes |
| | Airlines models (hub-and-spoke vs point-to-point) | - - - -<br>~ - 1 hour<br>(decreased planned travel time) | - - - - -<br>~ - 1.25 hour<br>(decreased planned travel time) | - - - - - -<br>~ - 1.5 hour<br>(decreased planned travel time) |
| | Enhanced connection times | - - -<br>~ - 0.75 hour<br>(decreased planned travel time)<br>(not cumulative with airlines models) | - - - -<br>~ - 1 hour<br>(decreased planned travel time)<br>(not cumulative with airlines models) | - - - - - -<br>~ -1.5 hour<br>(decreased planned travel time)<br>(not cumulative with airlines models) |
| | 'Pit stop' | - - -<br>(decreased planned travel time) | - - -<br>(decreased planned travel time) | - - -<br>(decreased planned travel time) |
| | High-speed trains | + | + + | + + |
| **H3. Policy / regulation** | | | | |
| Gate-to-gate | **NET IMPACT** | - - - - | - - - - | - - - - |
| | Single European Sky integration | - - | - - | - - |
| | Passengers' compensation | - - | - - | - - |

Note: – shows time saving; + shows time increase.
Impact colour coding:

- Based on KPIs target, division in the subpackages is extrapolated;
- Interpolated through average between Step 2 and Step 3;
- Modified with broader flight time reduction target;
- From validation exercises;
- Linear extrapolation using validation exercise and high-level target.

# 4. Advancing the model

## 4.1 Taking account of disruption

The primary goal of the high-level factor identification is to foresight several reference states for the future. Those future (2030, 2050) reference states will describe how the future supply could be in the future, taking into account a variety of high-level factors that will influence. For an initial approach, a reference state should be sufficient to provide a first insight on the performance of the air transport system and its implications in mobility in Europe. **In the long-term**, the complex air transport system is exposed to technological changes, regulations and economic evolution.

However, the air transport system is in parallel impacted in the **short-term** scale by constant disruptions in the daily operations. Such disruptions could originate, for instance, in the weather or in the behaviour of the organisations and stakeholders participating in the system. Those disruptions impact the performance of the system in the short scale, making it more or less vulnerable to those disruptions. The ability of a specific system to recover from short-term disruptions that appear as external forces in the evolution of the system is a quality normally known as 'resilience'. As described in the **Flightpath 2050**, one of the objectives for 2050 is that 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.

The **resilience of the current system** against a particular disruption is complex to measure. In principle, resilience should be measured by comparing the behaviour of the system in the absence of a particular disruption with its behaviour in the presence of that disruption. The en-route resilience of the current air transport system against a particular disturbance could be measured, for instance, measuring the delay of the arriving traffic using the affected route, against the delay that the traffic get using this route in a reference state (i.e. without disturbance). The delays distributions under the presence of the disturbance and the reference state can be compared, for instance, through comparing the slopes of the lineal regressions of those delay distributions (see the FP7 Resilience2050 project).

Measuring the resilience of the current system is an intensive data analysis exercise that requires different data management and efficient data processing capabilities. Measuring the resilience of the future scenarios is even a more complex exercise:

- On one hand, due to the **wide range of potential future reference states**: defining and forecasting how the transport system supply will have reacted to technological changes, regulations, policies and economic evolution. Pointing to a precise forecast state can be challenging for long-term scenarios such as 2050. The alternative is to provide a collection of potential reference states: less individually accurate but covering a wider range of possibilities (see EUROCONTROL STATFOR forecasts for 2050). This is ultimately the rationale behind the different granularity level of the DATASET2050 metrics and assessment for the current, 2035 and 2050 timeframes.
- As the data regarding **disturbances of future scenarios** are not available, the disruptions and disturbances need to be modelled, as well as the impact of those disruptions. In order to provide useful resilience insights, disturbed situations need to

be compared with the future references states. With this level of complexity and uncertainty, the resilience figures extracted would be most likely insignificant, on top of requiring a very high computational cost.

In this context, the DATASET2050 model tackles resilience in the following manner:

- Resilience is understood as the property measuring and dealing with the impact of disruptions and disturbances to the air transport system;
- Given its importance for mobility, it has been included as a **mobility focus area**. It has been grouped with “multimodality” and “diversity of destinations” within the “Flexibility” key performance mobility area. See DATASET2050 D5.1 for further details;
- The precise calculation and granularity of resilience figures and metrics follow the same approach as other mobility focus areas. As explained in Table 9. **Model inputs and resolution**: High granularity and real data for current (2015) scenario, medium granularity and a mix of qualitative and quantitative assessments for 2035 scenario, and a futuristic, high-level-only resolution for 2050.

## 4.2 Efficiency and compressibility

Having discussed various issues associated with disruption in the previous sub-section, and before we move on to trade-offs in the next sub-section, we turn here to the concept of ‘efficiency’, which will comprise a Key Performance Area to be addressed in Deliverable 5.1. We may define the efficiency of a D2D trip as the time taken to make the D2D journey as ratio of the *shortest* possible time with respect to the reference timeframe, with and without baggage. The ‘reference timeframe’ takes into account that the available modes, technologies and policies are likely to be significantly different by 2035 and 2050, and thus the shortest journey time possible in the future will be an improved reference with respect to the current timeframe. This clearly implicates compressibility, and a need to determine which components of the D2D journey time are compressible, or, expressed another way, the extent to which typical experiences under prevailing conditions are inferior to the optimal experience. We thus need to define what is defined by the shortest possible time (Table 25).

**Table 25: Shortest possible door-to-door components**

| Phase | Basic assumptions | Conditions |
|---|---|---|
| D2K | Fastest possible mode or combination of modes is selected | No congestion or disruption during the (intermodal) surface access journey(s) |
| K2G | Shortest possible time, (a) with, (b) without, bags[1], allowing for arrival at gate within minimum (boarding process) time specified by the carrier[2] | No check-in, baggage drop, security, passport control, or customs queues[3]; no elective wait, buffer or retail time for the passenger |
| G2G | Shortest terminal, taxi-out, *available* routing (not GCD) and taxi-in configurations | No ATFM delay or other disruption; no flight buffer time; MCTs[2] observed for connections |
| G2K | Shortest possible time, (a) with, (b) without, baggage reclaim[1] | No baggage reclaim, security, passport control, or customs queues[3]; no elective wait, (onward mode) buffer or retail time for the passenger |
| K2D | As per D2K | As per D2K |

[1] We thus assume that even in future timeframes airport processes for passenger may be quicker without bags. This may not be the case, e.g. with remote check-in and baggage delivery, in which case (a) = (b).
[2] These times are thus considered incompressible for the purposes of this measurement. In future timeframes they become less, but not zero.
[3] Alternatively, the 10th percentile of such queue times could be used.

This definition of efficiency assumes that the shortest travel time is 'best'. There are evidently **trade-offs with other KPIs**, notably cost-effectiveness, capacity and flexibility, and sustainability, which are very likely to be correlated with *longer* travel times, alternative routing options and reduced fuel burn, for example. Buffer times, adopted by airlines and passengers, are strongly related to prevailing policies and the associated (economic) penalty of being delayed relative to the planned time (e.g. forcing an airline to pay compensation, or a passenger to re-book a journey at considerable expense). The policy context is also a factor with regard to airport access and egress times, and journey accountability through ticket interoperability. More generically, these types of indicator are linked with **passenger utilities** (satisfaction from consuming a good or service) and values of time (which vary across waiting, delay and in-vehicle time), both of which in turn vary as a function of passenger type and trip purpose. Notably, passengers may prefer to have a certain amount of time at the airport for retail activities (and airports currently rely on such revenues). It is therefore important to differentiate between **objective and subjective** KPIs, as we discuss in Deliverable 5.1.

## 4.3 Trade-offs

Transport is a complex system, involving millions of travellers making myriad different door-to-door trips each day. In this framework, a large list of parameters and metrics measure and assess the performance of the mobility system at all levels. From individual passengers' time spent travelling, to aggregated metrics at a system level regarding punctuality. From aspects regarding air transport resilience, to geographic metrics relating to the connectivity of EU citizens depending on where they reside. In addition, strategic agendas such as Flightpath 2050 point to very specific targets, such as achieving **four-hour door-to-door journeys for 90%** of EU passengers with flights arriving **within 1 minute** of the planned arrival time, regardless of weather conditions.

This section identifies the different elements and metric trade-offs within DATASET2050. These trade-off exercises are key in the context of guiding policies regarding mobility supply-side elements. They are the basis for the proper future balance between transport supply and demand in future scenarios, avoiding future bottlenecks. They have been structured into two groups:

- **Metrics trade-offs:** is it worth enhancing one metric to the detriment of others? How to reach mobility targets via multivariable or multi-metric optimisation? Should we only consider trip duration?
- **Four-hour door-to-door trade-offs:** the different trade-offs between scenarios, all complying with the 4HD2D goal. How should these be prioritised?

### 4.3.1 Metrics trade-offs

The *preliminary* list of mobility metrics is based on ICAO's 11 Key Performance Areas (KPAs), as shown below, is further broken down into Mobility Focus Areas (MFAs: we give one example under several of the KPAs). Note that D5.1 details the final set of KPAs that will be used by DATASET2050.

Preliminary KPA list:

- Access and equity
    - Affordability
- Capacity
- Cost effectiveness
    - Value for money
- Efficiency
    - Duration
- Flexibility
    - Resilience
- Interoperability
- Participation and collaboration
- Predictability
    - Punctuality
- Safety
- Security
- Sustainability
    - Social (c.f. environmental)

The trade-offs in this context are understood as exercises comparing two or more of the above indicators. Questions such as, is it worth X extra cost for a Y reduction in door-to-door travelling time? This is an exercise regarding how indicators are prioritised in the future by the demand side: the mobility supply side should evolve towards covering areas that the demand side considers a priority. Otherwise, transportation bottlenecks and underperformance are expected. In this context, the passenger profiling already achieved is crucial to detect the requirements and preferences regarding EU mobility. The second DATASET2050 workshop will provide key insights regarding these trade-offs.

The MFA directly measuring the four-hour door-to-door concept is the **duration** (MFA), under the efficiency (KPA). Once all the metrics are defined (see D5.1), some of them will be calculated using the model in D5.2. Specifically, those with sufficient data to support them and with a reasonable computational cost. Afterwards, the trade-off assessments between the different metrics will be incorporated in D5.3: "The novel concept foundations for European Mobility".

### 4.3.2 Four-hour door-to-door distribution trade-offs

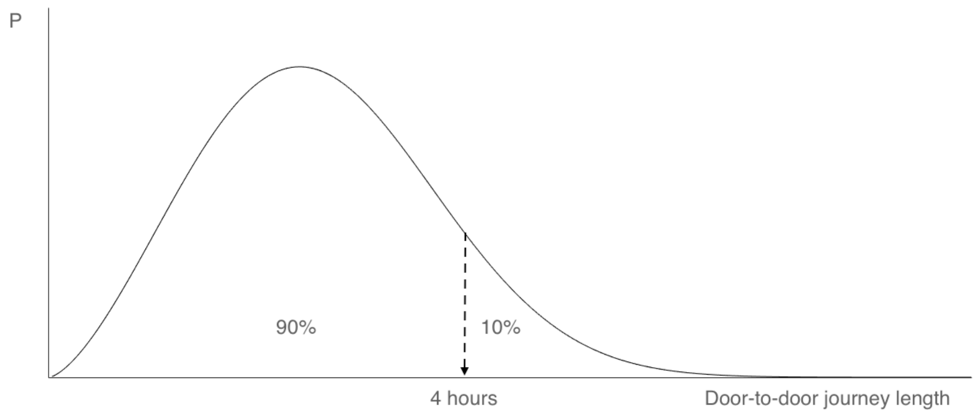



**Figure 10: Door-to-door journey length**

As already introduced in D2.2, every modification of the air transportation supply system will affect the door-to-door duration indicator in a unique way. For instance, when looking at Figure 10, a modification (technical, regulatory, intermodal) may lead to:

- A distribution curve with a similar shape, but shifting to the left / right: correspondingly nearer to / further from the four hours' mobility objective;
- The curve changing shape: increasing the peak height, width and/or modifying the shape of the tail;
- Any combination of the previous two points.

There are several ways to achieve the four-hour door-to-door goal for 90% of travellers, as inherent in the somewhat generic definition of the metric. In each strategy, the individual passenger experience is different but it would fulfill the global 90% 4HD2D metric at the overall (European) scale. The following examples, based on 100 passengers, illustrate this:

- 90 passengers making a **3h 50m** trip, plus 10 passengers making a **4h 10m** trip;
- 90 passengers making a **1h** trip, plus 10 passengers making **8h** trips;
- 50 passengers making a **2h** trip, 30 passengers making a **3h** trip, 5 passengers making a **4h 10m** trip and 5 passengers making a **5h** trip;
- 90 passengers making the trip below **4h**, 10 passengers requiring more than **4h**.

As may be extracted from the example below, different distributions shape the door-to-door goal. Figure 11 shows an example of different Weibull distributions (in terms of probability density functions with different eta and beta values), but the underlying idea is valid for any other function.

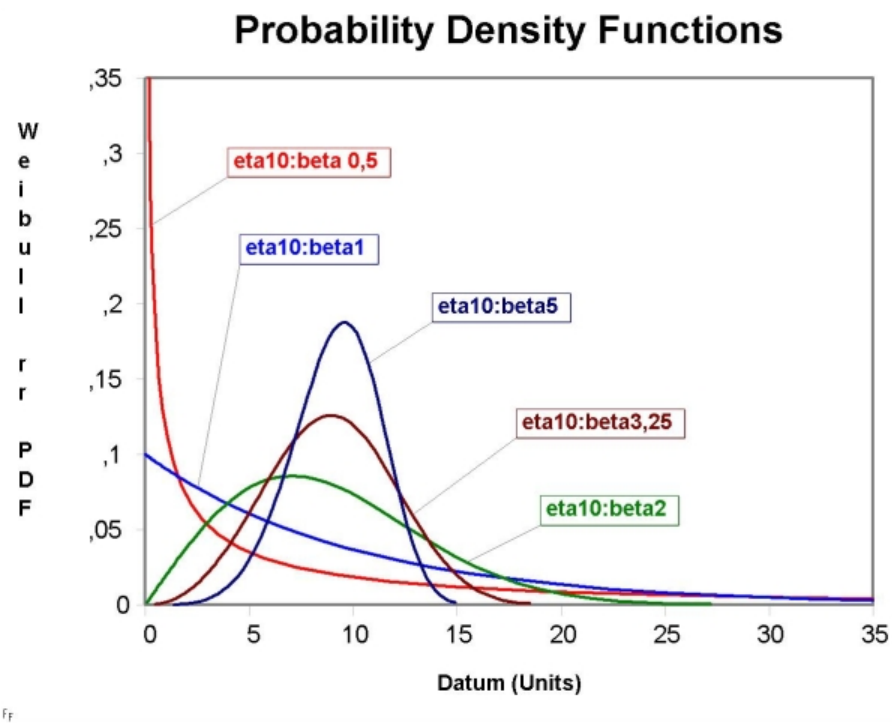



Figure 11: Four-hour door-to-door different distributions

There are different scenarios/curves, all complying with the long-term objective of the four-hour door-to-door goal. In this context, the trade-offs can be also understood as the exercise of selecting the most advantageous 4HD2D scenario for EU passengers. In other words, the most 'convenient' shape of door-to-door journey length distribution preferred by travellers.

On the one hand, the metrics calculated in D5.2 will provide us with a fixed distribution for the current 2015 status. On the other hand, the assessment of future mobility provided by D5.3 should identify and prioritise future curve distributions, making a trade-off between the different scenarios that comply with the four-hour door-to-door metric.

# 5. Data management and outputs for WP5

## 5.1 Summary of model impacts

The following tables summarise the expected net impact on travel time in 2035 and 2050 of the various high-level group parameters discussed in Section 3. For instance, the first 'door-to-kerb (& kerb-to-door)' row estimates the **overall** D2K/K2D net impact on future travel time of an ageing population, population growth, urbanisation and so on, as shown in Table 17. These impacts will be taken forward to WP5.

**Table 26: Summary of the expected net impact of journey phase parameters per high-level group on 2035 travel time**

| Parameters | 2035 | | |
|---|---|---|---|
| | **Model scenario 1: weak supporting changes** | **Model scenario 2: expected supporting changes** | **Model scenario 3: strong supporting changes** |
| **H1. Traffic / demand** | | | |
| Door-to-kerb (& kerb-to-door) | **~0** | + | + + + + |
| Kerb-to-gate (& gate-to-kerb) | + | + | + |
| Gate-to-gate | + | + | + |
| **H2. Market forces / technologies / supply** | | | |
| Door-to-kerb (& kerb-to-door) | – | – | – – – – |
| Kerb-to-gate (& gate-to-kerb) | – – – – | – – – – – | – – – – – – |
| Gate-to-gate | – – – – | – – – – – | – – – – – – – |
| **H3. Policy / regulation** | | | |
| Door-to-kerb (& kerb-to-door) | + | + | + + + + |
| Kerb-to-gate (& gate-to-kerb) | **~0** | – | – |
| Gate-to-gate | – – | – – | – – – – |

Note: – shows time saving; + shows time increase.

**Table 27: Summary of the expected net impact of journey phase parameters per high-level group on 2050 travel time**

| Parameters | 2050 | | |
|---|---|---|---|
| | **Model scenario 1:** weak supporting changes | **Model scenario 2:** expected supporting changes | **Model scenario 3:** strong supporting changes |
| **H1. Traffic / demand** | | | |
| Door-to-kerb (& kerb-to-door) | ~0 | + | +++++ |
| Kerb-to-gate (& gate-to-kerb) | ++++ | ++++ | ++++ |
| Gate-to-gate | + | + | + |
| **H2. Market forces / technologies / supply** | | | |
| Door-to-kerb (& kerb-to-door) | --- | ----- | ------ |
| Kerb-to-gate (& gate-to-kerb) | ----- | ------ | ------- |
| Gate-to-gate | ------- | ------- | --------- |
| **H3. Policy / regulation** | | | |
| Door-to-kerb (& kerb-to-door) | + | ++++ | +++++ |
| Kerb-to-gate (& gate-to-kerb) | – | – | – |
| Gate-to-gate | ---- | ---- | ---- |

Note: – shows time saving; + shows time increase.

## 5.2 Data management

Table 28 consolidates the **available current data** for each journey phase (2015 or most recent year available). Data for the door-to-kerb/kerb-to-door and kerb-to-gate/gate-to-kerb journey phases are shown as pairs rather than sequential order to assist the reader, i.e. some data will be derived from a preceding phase. In some cases, missing times can be calculated using expert assumptions.

**Table 28: Summary of the availability of current data by journey phase**

| Phase | Data | Airport archetype | | | |
|---|---|---|---|---|---|
| | | Main hub (4 airports) | Secondary hub (13 airports) | Large/medium (27 airports) | National/regional (156 airports) |
| D2K | Private mode % | 6 | 6 | 5 | 5 |
| D2K | Public mode % | 6 | 5 | 5 | 5 |
| D2K | Private access time | 2 (a) | 5 | 2 (a) | 4 |
| D2K | Public access time | 2 (a) | 5 | 2 (a) | 4 |
| K2D | Private mode % | *derived from D2K* | *derived from D2K* | *derived from D2K* | *derived from D2K* |
| K2D | Public mode % | *derived from D2K* | *derived from D2K* | *derived from D2K* | *derived from D2K* |
| K2D | Private access time | *derived from D2K* | *derived from D2K* | *derived from D2K* | *derived from D2K* |
| K2D | Public access time | *derived from D2K* | *derived from D2K* | *derived from D2K* | *derived from D2K* |
| G2G | Boarding time | *generic (b)* | *generic (b)* | *generic (b)* | *generic (b)* |
| G2G | Transfer % | 5 | 5 | 5 | 5 |
| G2G | Minimum connecting time | 3 | 3 | 3 | 3 |
| G2G | De-boarding time | *generic (b)* | *generic (b)* | *generic (b)* | *generic (b)* |
| K2G | Time to terminal door | 3 | 3 | 7 | 7 |
| K2G | Walking time in airport | 3 (b) | 3 (b) | 7 | 7 |
| K2G | Check-in time | 6 | 6 | 6 | 7 |
| K2G | Bag-drop time | 6 | 6 | 6 | 7 |
| K2G | Security time | 6 | 6 | 5 | 6 |
| G2K | Immigration time | 6 | 6 | 6 | 7 |
| G2K | Bag-reclaim time | 6 | 6 | 6 | 7 |
| G2K | Customs time | 7 | 7 | 7 | 7 |
| G2K | Time from terminal door | *derived from K2G* | *derived from K2G* | 7 | 7 |

**Examples of available data:**

(a) UK travel time dataset for 30+ airports; modelled access time for private transport and public transport trips in 2011;

(b) Calculated times from DATASET2050 D4.1.

**Data availability rating:**

1 Explicit data (n > 500) for at least 40% of airports;

2 Explicit data (n > 500) for at least 20% of airports;

3 Minimum, maximum, average times(/percentages) for at least 20% of airports;

4 Minimum, maximum, average times(/percentages) for at least 10% of airports;

5 Average times(/percentages) for at least 3 airports;

6 Average time(/percentage) for 1 airport;

7 Less.

# 6. References

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# 7. Acronyms, abbreviations

| | |
|---|---|
| 4HD2D: | Four-hour door-to-door |
| ACARE: | Advisory Council for Aviation Research and Innovation in Europe |
| ACI: | Airports Council International |
| ASAS: | Airport surface access strategy |
| A-SMGCS: | Advanced Surface Movement Guidance and Control System |
| ATM: | Air Traffic Management |
| BHL: | Short name of DATASET2050 partner: Bauhaus Luftfahrt |
| $CO_2$: | Carbon dioxide |
| CSA: | Coordination and Support Action |
| CSR: | Corporate social responsibility |
| D2D: | Door-to-door (mobility concept) |
| D2K: | Door-to-kerb |
| DATASET2050: | Data-driven approach for a seamless efficient travelling in 2050 |
| DX.Y: | Deliverable's name (X=workpackage, Y=deliverable numbering within workpackage) |
| EC: | European Commission |
| ECTL: | Short name of DATASET2050 partner: EUROCONTROL |
| EFTA: | European Free Trade Association |
| ETS: | European Trading Scheme |
| EU: | European Union |
| EU-28: | European Union 28 member countries (since July 2013) |
| FFP: | Frequent flyer programme |
| FP7: | Seventh Framework Programme for Research and Technological Development |
| G2G: | Gate-to-gate |
| G2K: | Gate-to-kerb |
| GCD: | Great circle distance |
| H2020: | Horizon 2020 research programme |
| HS2: | High Speed 2 (planned rail link) |
| HUCL: | High utilisation airports – complex |
| HUSL: | High utilisation airports – simple |
| IATA: | International Air Transport Association |
| ICAO: | International Civil Aviation Organization |
| INX: | Short name of DATASET2050 coordinator: Innaxis |
| K2G: | Kerb-to-gate |
| KPA: | Key performance area |
| KPI: | Key performance indicator |
| LCC: | Low-cost carrier |
| LUCL: | Low utilisation airports – complex |
| LUSL: | Low utilisation airports – simple |

| | |
|---|---|
| MCT: | Minimum connecting time |
| MFA: | Mobility Focus Areas |
| MG: | Mobility for growth (H2020 theme) |
| mppa: | Million passengers per annum |
| $NO_x$: | Oxides of nitrogen |
| R&D: | Research and development |
| RFID: | Radio-frequency identification |
| SESAR: | Single European Sky ATM Research |
| SRA: | Swedish Road Administration |
| STEEP-M: | Social, technological, economic, environmental, political and mobility |
| TBO: | Time-Based Operations |
| TE: | Time-efficient (airport) |
| UoW: | Short name of DATASET2050 partner: University of Westminster |
| WP: | Workpackage |
| XXX: | IATA 3 letter airport codes (e.g. MAD: Madrid airport) |

# Appendix 1. STEEP-M clustering results

Results from the STEEP-M clustering process, described in Section 2.1.
Table columns:

- **High-level (factor) group:** grouped into H1 (traffic/demand); H2 (market forces/technologies/supply); H3 (policy/regulation);
- **Factor:** states the factors that are addressed across the three model scenarios;
- **Projection:** outlines the different paths a factor might take in the future;
- **(High) growth of world economic development:** model scenario outlining the developments taking place if we have high economic growth;
- **Status quo of world economic development:** model scenario outlining the developments taking place if we have expected economic growth;
- **Decline of world economic development:** model scenario outlining the developments taking place if we have weak economic growth.

| High-level (factor) group | | Factor | Projection | (High) growth of world economic development | Status quo of world economic development | Decline of world economic development |
|---|---|---|---|---|---|---|
| Social | H1 | Ageing population | Increasing | Increasing | Increasing | Increasing |
| | H1 | Population growth | Increasing | Increasing | Increasing | Increasing |
| | H1 | Social well being | High level | | | |
| | | | Medium level | Medium level | Medium level | Medium level |
| | | | Low level | | | |
| | H1 | Middle class development | Increasing share | Increasing share | Increasing share | |
| | | | Stagnation | | | Stagnation |
| | | | Decreasing share | | | |
| | H1 | Urbanisation | Increasing | Increasing | Increasing | Increasing |
| Technological | H2 | Innovation | Breakthroughs | Breakthroughs | | |
| | | | Improvements | | Improvements | |
| | | | Stagnation | | | Stagnation |
| | H2 | Information and communication technologies | Increase | Increase | Increase | |
| | | | Status quo | | | Status quo |
| | | | Decrease | | | |
| | H2 | Green innovation | Breakthroughs | | | |
| | | | Improvements | Improvements | Improvements | |
| | | | Stagnation | | | Stagnation |
| | H2 | Global collaboration in R&D | Integrated research | | | |
| | | | Coordinated research | Coordinated research | Coordinated research | Coordinated research |
| | | | Fragmented research | | | |

| High-level (factor) group | | Factor | Projection | (High) growth of world economic development | Status quo of world economic development | Decline of world economic development |
|---|---|---|---|---|---|---|
| Economic | H1 | Consumer demand | Heterogenous | Heterogenous | | |
| | | | Balanced | | Balanced | Balanced |
| | | | Homogenous | | | |
| | H2 | Supply chain costs | Increase | | Increase | |
| | | | Status quo | | | Status quo |
| | | | Decrease | Decrease | | |
| | H2 | Competition for scarce resources | High | High | | |
| | | | Medium | | Medium | Medium |
| | | | Low | | | |
| | H3 | International cooperation and exchange | Globalisation | Globalisation | | |
| | | | Regionalisation | | | Regionalisation |
| Environmental | H2 | Emissions | Increase | Increase | | |
| | | | Status quo | | Status quo | Status quo |
| | | | Decrease | | | |
| | H1 | Energy demand | Increase | Increase | | |
| | | | Status quo | | Status quo | Status quo |
| | | | Decrease | | | |
| | H1 | Environmental awareness | High | High | | |
| | | | Medium | | Medium | |
| | | | Low | | | Low |
| | H3 | Effects of climate change | Significant | | Significant | |
| | | | Moderate | Moderate | | Moderate |
| Political | H3 | Regulations | Increase | | | |
| | | | Status quo | Status quo | Status quo | Status quo |
| | | | Decrease | | | |
| | H3 | Green policies | Increase | | | |
| | | | Status quo | Status quo | Status quo | |
| | | | Decrease | | | Decrease |
| | H3 | Multipolar world | Increase | Increase | Increase | |
| | | | Status quo | | | |
| | | | Decrease | | | Decrease |
| | H3 | Global conflicts | Increasing amount of wars | | | |
| | | | Predominantly violent crises | | | |
| | | | Predominantly non-violent crises | Predominantly non-violent crises | | Predominantly non-violent crises |
| | | | Mainly disputes or no crises | | Mainly disputes or no crises | |

| High-level (factor) group | | Factor | Projection | (High) growth of world economic development | Status quo of world economic development | Decline of world economic development |
|---|---|---|---|---|---|---|
| **Mobility (Aviation)** | **H1** | Aviation infrastructure capacity | Sufficient supply | | | |
| | | | Capacity shortages restricted to certain areas | Capacity shortages restricted to certain areas | Capacity shortages restricted to certain areas | Capacity shortages restricted to certain areas |
| | | | Severe overall capacity shortages | | | |
| | **H1** | Air transport demand | Increase | Increase | | |
| | | | Status quo | | Status quo | Status quo |
| | | | Decrease | | | |
| | **H3** | Perception of air transport | Positive | | | |
| | | | Divergent | Divergent | Divergent | Divergent |
| | | | Negative | | | |