DATASET2050

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

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Deliverable 3.2

"Future Passenger Demand Profile"

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ABSTRACT

The FlightPath 2050 goal of enabling 90 per cent of European passengers to complete their door-to-door journey within four hours is a very challenging task. A major objective of the DATASET2050 project is to deliver insight into both current and future processes relating to the European transport system in this context.

The deliverable D3.2 "Future Passenger Demand Profile" focuses on the future demand side of European (air) transport. Namely, the first goal is to develop a range of passenger profiles for the year 2035 and to provide implications for passenger profiles for 2050. For this purpose, the development of passenger characteristics - including demographic, geographic, socio-economic and behavioural aspects as well as particular mobility patterns - is analysed using available European data and forecasts.

Based on this analysis, on specific mobility behaviour of the different member states (EU28 and EFTA countries) as well as on a high-level-factor identification, six different passenger profiles for 2035 are developed. These six profiles differ by main travel purpose (private, business and leisure, which is the combination of business and leisure trips), predominant age group, income level (low, medium, high) and several other characteristics. Furthermore, a demand model is applied showing the high relevance of gross domestic product (GDP) and education for a steady growth of passenger traffic volume in the EU28 and EFTA countries until 2050.

The outcomes of the current deliverable will be put in contrast with those coming from D4.2 (Future supply profile), enabling thus a comprehensive assessment on the European door-to-door mobility in the future. Specifically, the deliverable results will be used in D5.1 (Mobility assessment), D5.2 (Assessment execution) and D5.3 (Novel concept foundations for European mobility).

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1 INTRODUCTION

1.1 Introduction to DATASET2050

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. It 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 European door-to-door** 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. Its main focus is to analyse how the **European transport supply profile** (capacity, connections, business models, regulations, intermodality, processes, infrastructure) adapts to **the demand profile** (customers, demographics, passenger expectations, requirements);
- DATASET2050 addresses the **main transport mobility goal** stated in the EC's FlightPath 2050 [EC, 2011]: in 2050, 90 per cent of travellers within Europe will be able to complete their journey, door-to-door within 4 hours. Through application of statistical analyses, multi-modal mobility modelling and predictive analytics, DATASET2050 will compute the **current status and future prediction** 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 hours door-to-door goal** formulated by ACARE. Due to the multi-dimensionality of the problem, DATASET2050 will use visualisation techniques, to ease the consumption 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 Introduction to D3.2

In line with the FlightPath 2050 goal of enabling 90 per cent of European travellers to complete their door-to-door journey within four hours (4hD2D), this report will set its focus on delivering insights into the future European air transport system and future passengers. To explore how the passenger of the future might look like, a first step is to examine the factors that drive air transport demand. As these demand drivers might change in the future, a better understanding of the resulting effects on demand is crucial to see how passenger profiles might change as well.

Demand is driven by various external and internal factors. External factors refer to economic and demographic conditions and internal factors encapsulate drivers such as quality of service and ticket price (Suryani et al., 2010). Many have already been described and examined in D3.1 as well as within other studies, like Andreoni and Postorino (2006), Chèze and Chevallier (2011), Dargay and Hanly (2001), Kopsch (2012) and Lyneis (2000). Different research methods such as econometric models and qualitative expert questionnaires have been used.

Present studies tend to be a good basis to explain the drivers of passenger air transport demand, however, many of these only take a small number of explorative variables into account or solely set focus on specific developments (e.g. fuel price development or population growth). Within this report, we will take a more holistic view to predict passenger (pax) demand and to describe future passenger profiles.

In order to do so, the report is structured the following way. In section 2 the main drivers for forecasting air transport passenger demand will be identified and presented. On the on hand, these drivers are the results of a high-level factor identification (section 2.2). On the other hand, more detailed future developments of demographical, geographical, socio-economic and behavioural aspects characterising passengers as well as mobility aspects will be examined (sections 2.3 to 2.8). In Part II of the report, the findings of Part I are applied using the multi-method modelling tool AnyLogic. Here, a simulation will be conducted to predict future passenger demand in 2035 and 2050 based on publicly available data (section 3). Finally, implications for future air transport passenger profiles will be derived, complemented by the modelling of respective passenger trips (section 4). The whole research process is depicted in Figure 1.

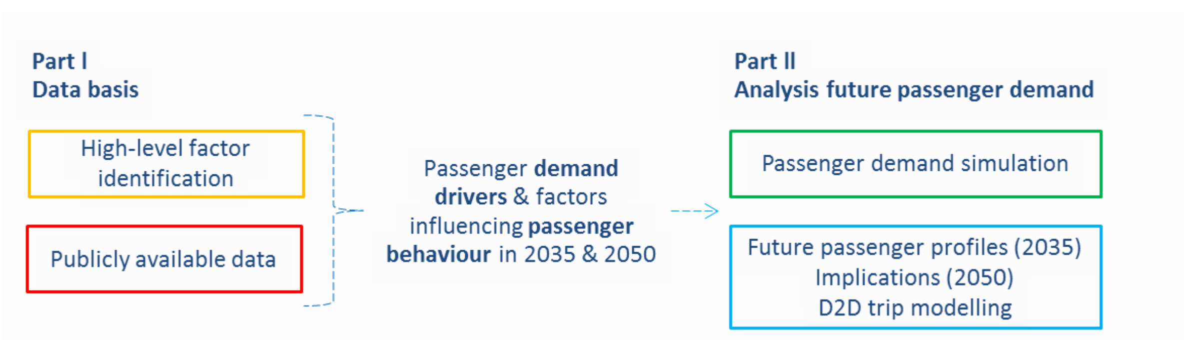

Figure 1: Derivation Future passenger demand (own depiction)

The content will build upon results from D3.1 and focus on the EU28 and EFTA countries. The simulation will focus on external factors only. The report will mainly analyse two milestones, the year 2035 and 2050.

2 PART ONE: DRIVERS PASSENGER DEMAND

2.1 Overview driver

The DATASET2050 report D3.1 explores a variety of demographic, geographical, socio-economic and behavioural factors, as well as mobility aspects, influencing the demand for mobility in general and for air transport in particular. In line with the distinction made in the introduction, these factors are external drivers. All of them are depicted in Figure 2. However, these factors are projected to change in the future and, hence, depending on their progressions, will also drive and change European air transport passenger demand in 2035 and 2050. The following section will elaborate on prospective developments as well as outline the interdependencies between these factors and derive implications. All factors have already been described and its influence on transport as well as passengers has been discussed in D3.1. Hence, based on this, the focus within this report will be on the **future development** of these factors and possible implications for the future transport system.

Within this report, a data driven approach will be taken and creating future scenarios is also a question of data availability. Other factors are more of qualitative nature (e.g. "environmental awareness" or "value of travel time"). Therefore, it can be challenging to find publicly available forecast data for some of these drivers and where possible, data is provided. Otherwise, implications and presumptions are given. If possible, data is provided for EU28 and all EFTA countries. Otherwise, again due to data unavailability, appropriate regions are used, such as Eastern and Western Europe.

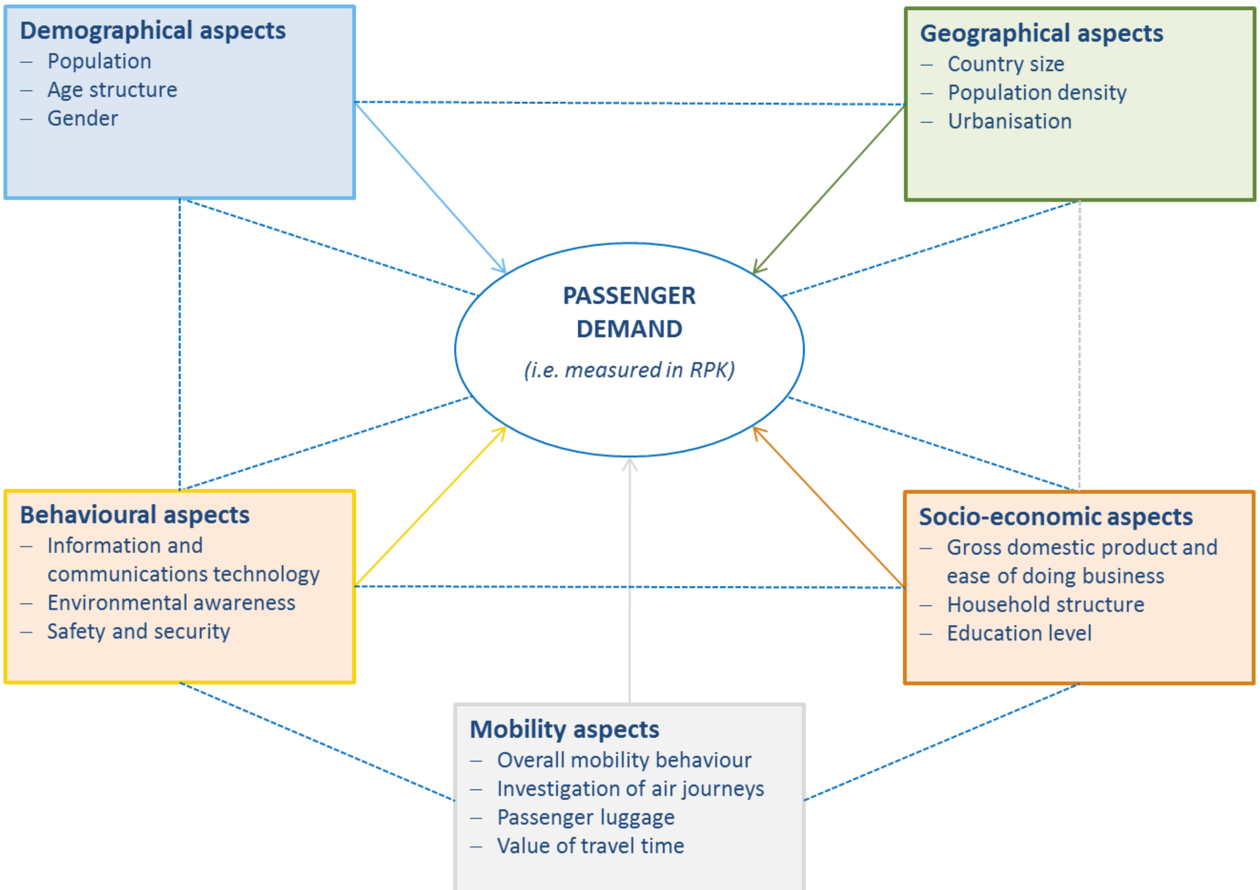

Figure 2: Drivers affecting passenger demand (own depiction)

2.2 High-level factor identification

As stated in the introduction, current studies tend to focus mostly on only a few factors or a specific development to forecast passengers' future air transport demand. The goal of the high-level factor identification is to attain a more comprehensive and thorough picture of the future environment and its drivers. For this purpose, a methodology that aggregates a variety of scenario studies and develops high-level factor groups was used (STEEP-M). All results can be found in D4.2. They provide a basis for a common picture of the future within the DATASET2050 project. This helps not just to understand how passengers will travel in 2035 and 2050 but also what will shape their everyday life.

Looking at rate of occurrence of different factors across all investigated studies (Figure 3), world economic development, innovation and emissions are the most relevant factors for 2035 and 2050 and predicting the future world. It can clearly be seen that world economic development has the highest relevance. Additionally, numerous studies have proven that GDD (taken here for world economic development) drives passenger demand strongly (i.e. Chèze & Chevallier (2011); Dobruszkes, Lennert & van Hamme, (2011); Kopsch (2012); Lyneis (2000) and Pearce (2008)).

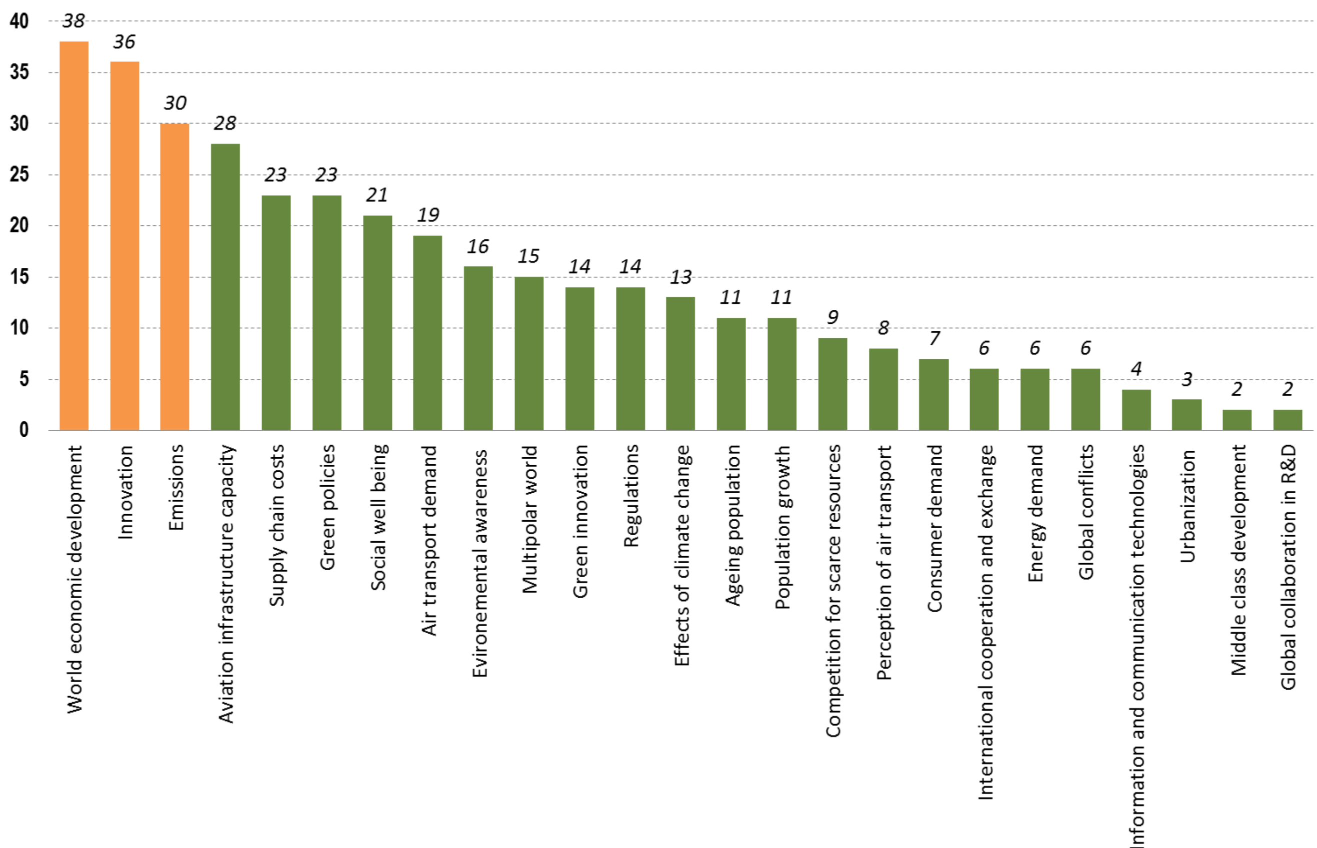

Figure 3: Occurrence of factors across all scenario studies with impact on passenger demand (own depiction)

2.3 Demographical drivers

2.3.1 Population

According to forecasts by the United Nations Population Division (UN, 2015), the overall population in the EU28 and EFTA countries will increase slightly until 2035 and experience a decrease in the years up to 2050 ("medium variant scenario"). However, as can be seen in Figure 4, some countries experience a decline in overall population whereas other countries face increasing numbers. Germany, Italy, Spain, and Poland, for example, belong to the former group. For the United Kingdom, France, Sweden or Norway, on the contrary, rising population figures throughout the course of the next 35 years are predicted. The share of females and males is assumed to be at the same level, around 50 per cent in all considered countries. Hence, there is no overall change compared to today. Differences arise in regard to different age groups, i.e. more females in the age groups of 65 years and older. A closer look at the changing age structure will be provided further below.

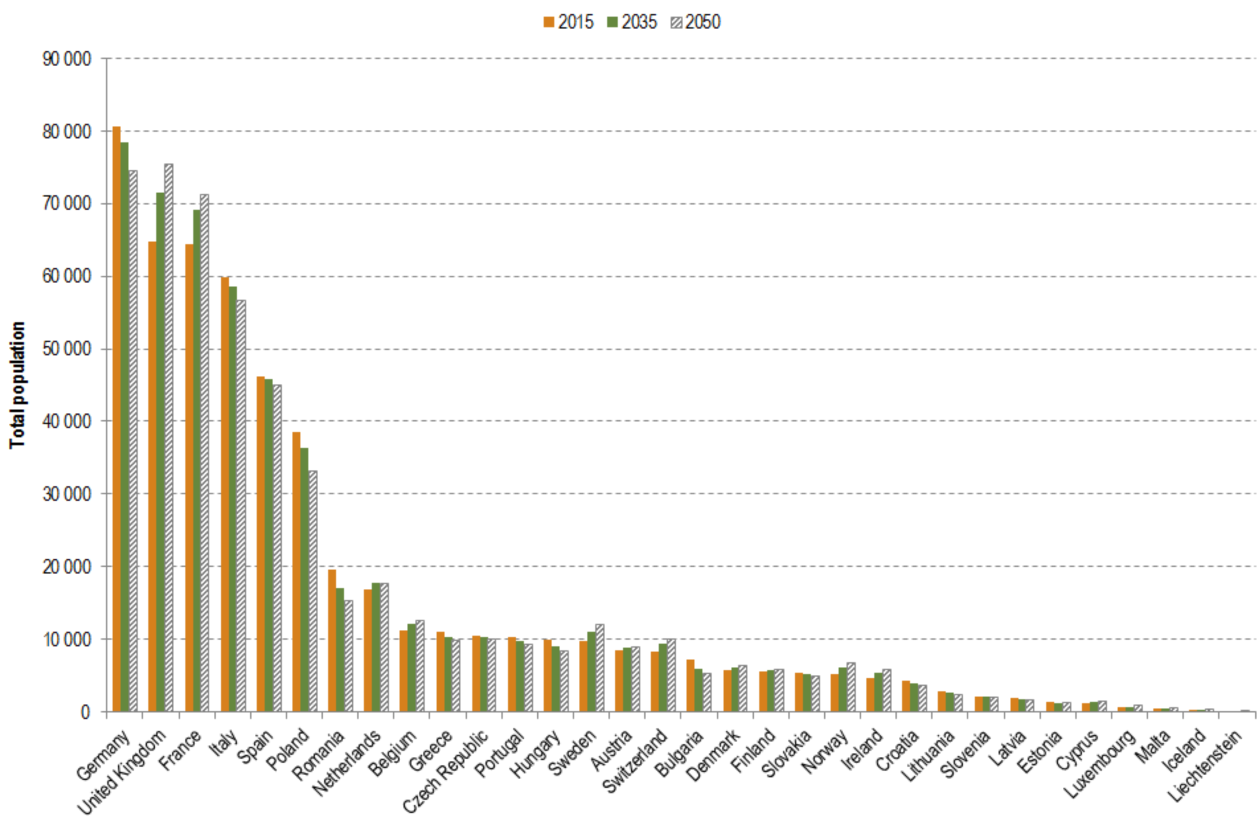

Figure 4: Development of overall population until 2050 (data: UN, 2015)

2.3.2 Age structure

Figure 5 gives an aggregated overview of the shift of age group shares in total population over time for the EU28 countries. Until 2050 the share of people aged 65 and above will increase from about 20 per cent today to about 30 per cent. The age group share of children aged 0 to 14 remains stable over time whereas the working age population (ages 15 to 64) is predicted to shrink from 66 per cent today to 57 per cent in 2050.

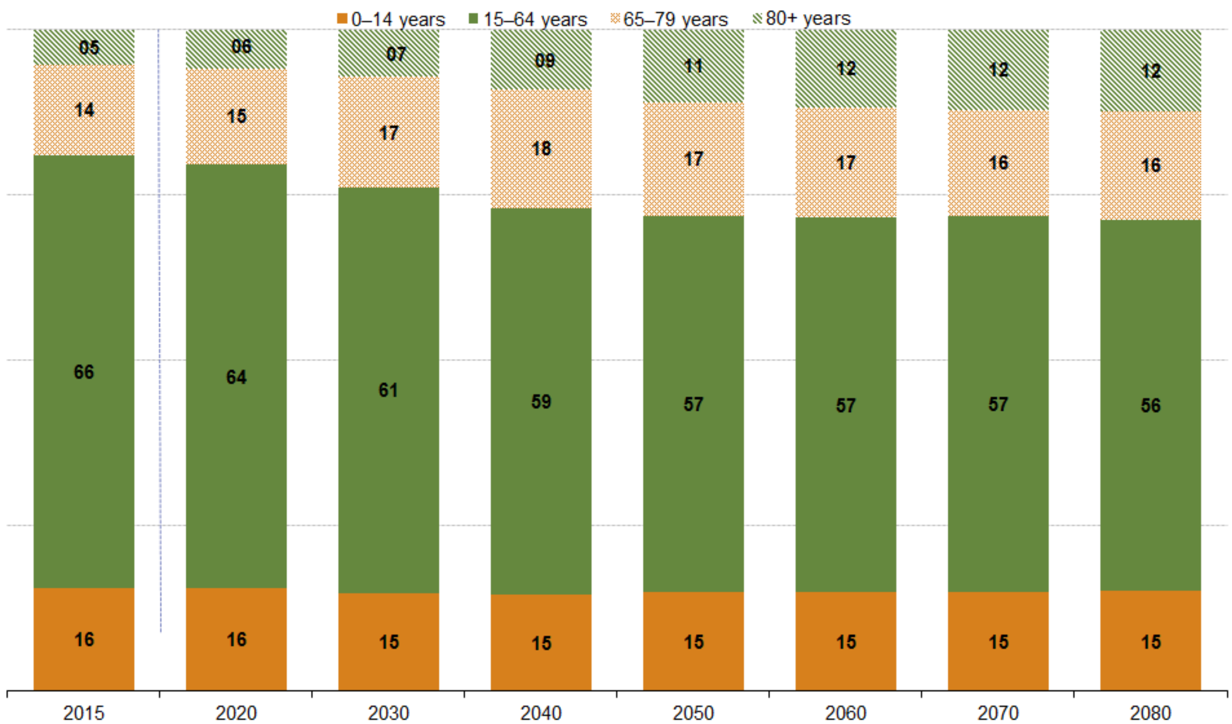

Figure 5: Changing age structure within Europe (data: Eurostat, 2016a)

Taking a closer look at the next figures, the changing age structure within Europe in the coming decades is also driven by an increasing average life expectancy across EU28 and EFTA countries. For females, the average life expectancy rises from an average 83 in 2015 to about 88 in 2050. Males, on the contrary, have a lower average life expectancy with 77 years in 2015 and 83 in 2050.

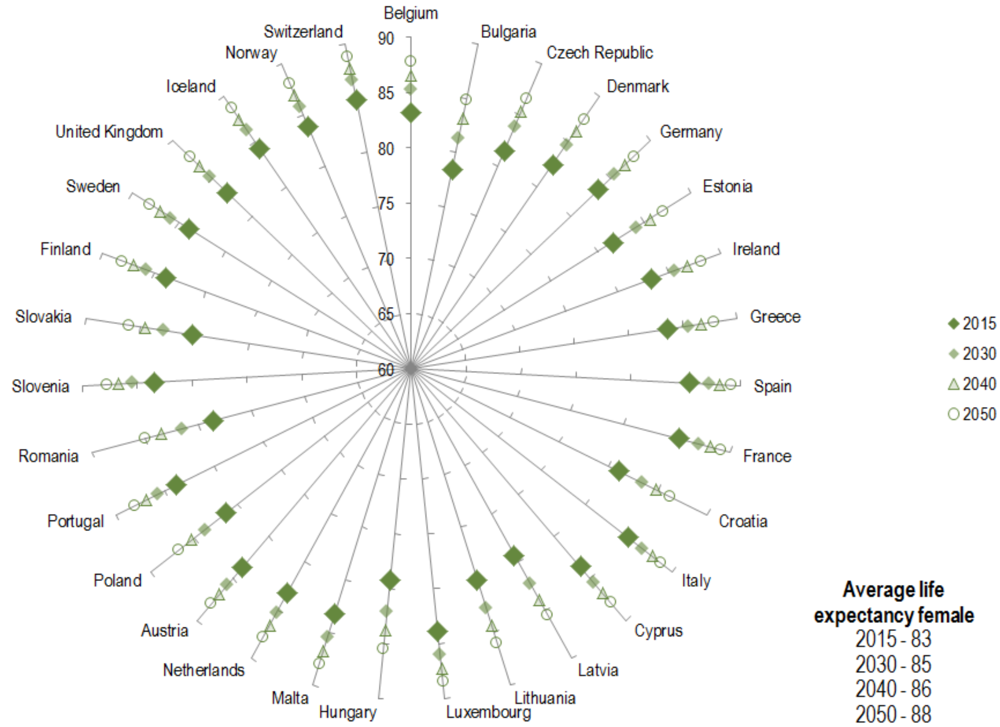

Figure 6: Development of average life expectancy across Europe (data: Eurostat, 2016d)

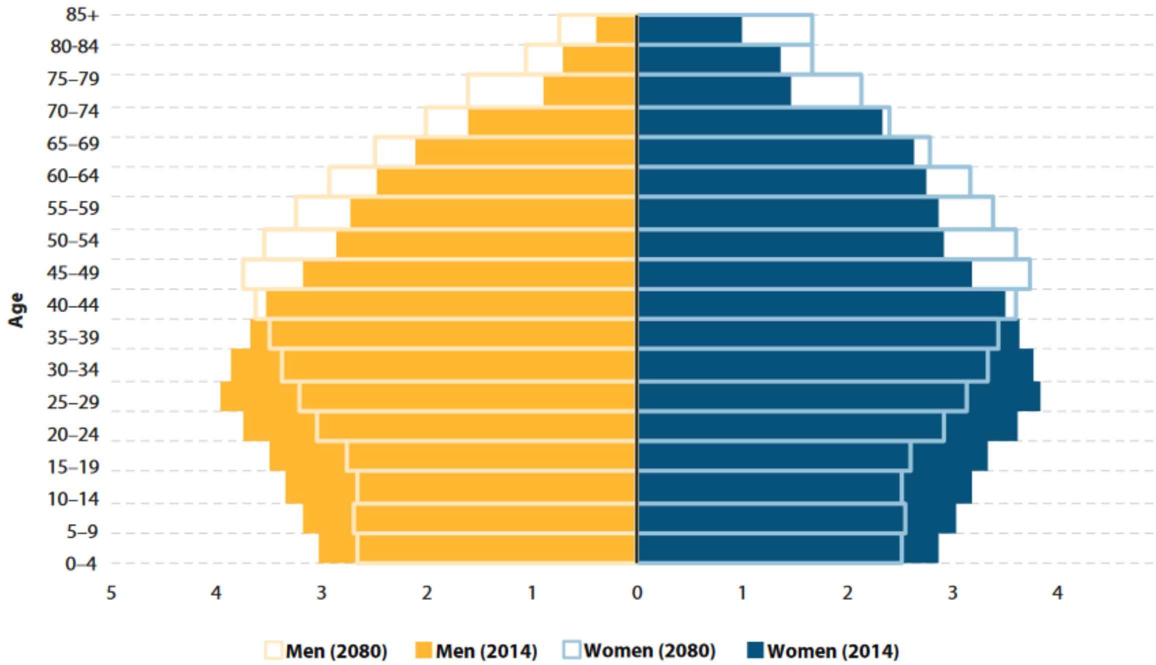

Figure 7: Population structure by age and sex, EU28, 2014 and 2080 (data: Eurostat, 2015)

As already addressed in the current passenger profiles (D3.1) and within other models (i.e. IATA, 2016), the age of passengers influences travel behaviour. Since people aged 65 and above are usually retired they have more free time available as well as sufficient financial funds to travel in order to get to know new places or visit family and friends. The number of people within this particular group increases up to 2035 and 2050 (as can be seen in Figure 7). Today's travellers of the ages 65+ have a lower overall travel activity than their younger counterparts (IATA, 2016). However, the latter, i.e. those with the highest travel activity today, will constitute the elderly travellers in the future. And different studies have shown that today's travel behaviour of a particular group is likely to determine their future travel patterns (see D3.1).

2.4 Geographical drivers

2.4.1 Urbanisation, population density and country size

The level of urbanisation, also analysed in the previous report on current passenger demand profiles (D3.1), is predicted to increase across the different countries considered within this analysis. Figure 8 shows the degree of urbanisation for 2015, 2035, and 2050, and it is evident for all countries that the share of population living in urban areas will increase even further in the considered timeframe.

All countries apart from Liechtenstein will have an urbanisation level of at least 60 per cent. Since a high share of population will live in cities, fast and reliable accessibility to respective airports has to be ensured. Furthermore, infrastructure capacity is limited and cannot be adjusted continuously according to travel demand. Hence, solutions must be geared towards the efficient use of existing infrastructure supply.

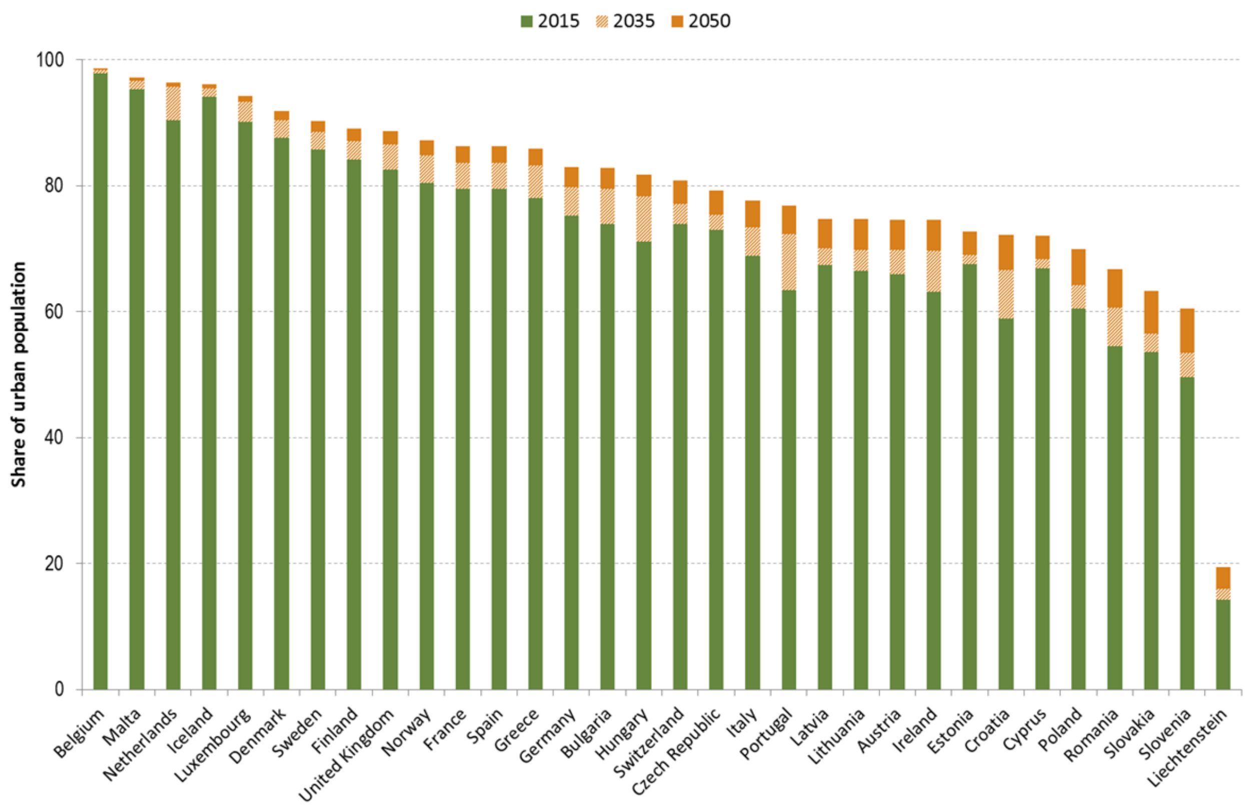

Figure 8: Development of urbanisation levels (data: UN, 2015)

On a global scale, Europe and Northern America are those regions with the highest degree of urbanisation (see Figure 9), both up to today and regarding future prospects. The bubbles represent the population size of different countries within the defined regions. Those with more than one billion inhabitants in Asia, for example, show China and India.

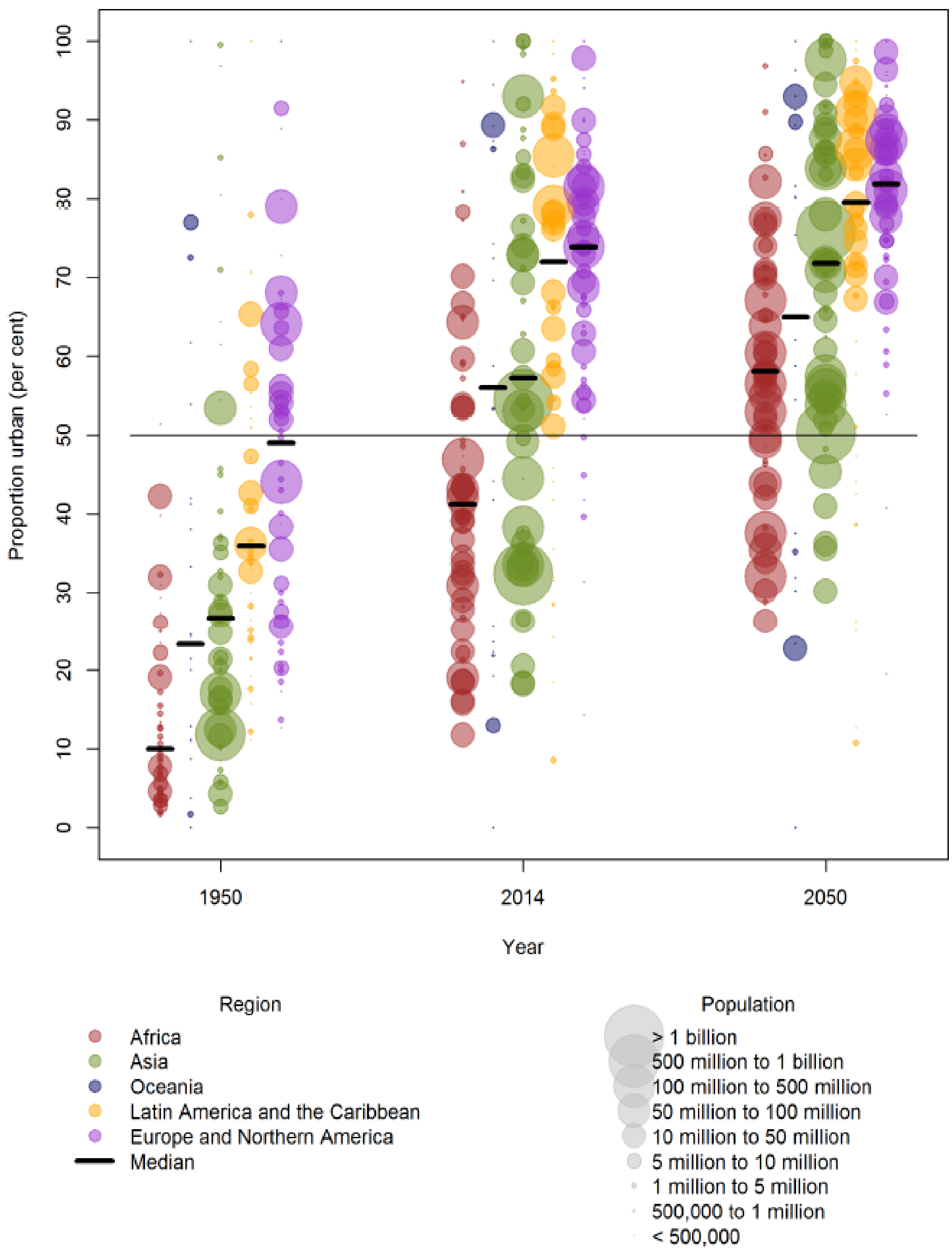

Figure 9: Comparison of share of urban population across world regions (data: UN, 2015)

Figure 9 and Figure 10 also give an insight into future urban development. Within Europe, there are only four cities predicted to have more than five million inhabitants in 2030. And two of these four, namely London and Paris, are to have more than 10 million people living in these urban agglomerations. As can also be seen, strong urban growth is taking place both in China and India.

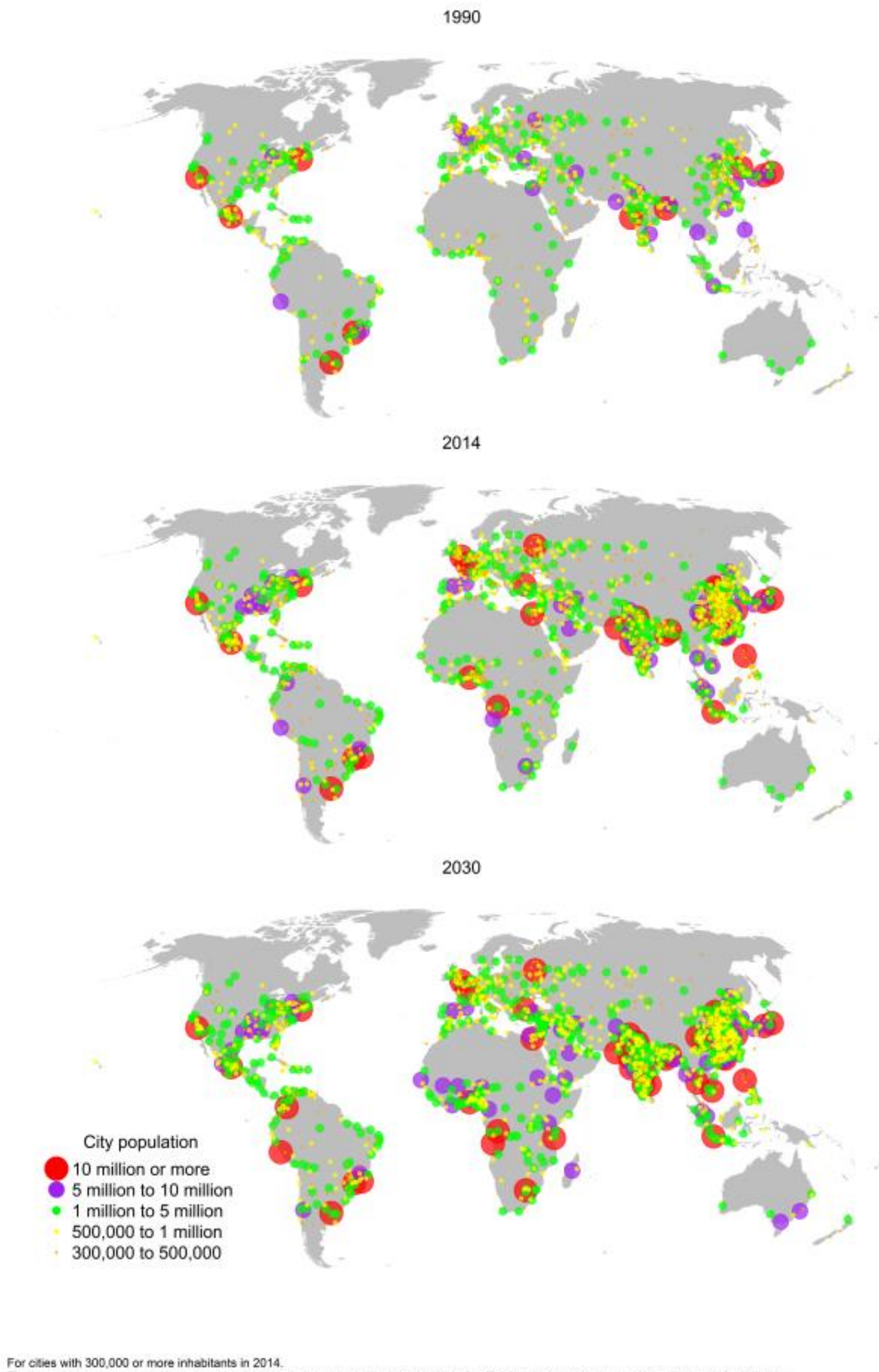

Figure 10: City population worldwide (data: UN, 2015)

With Europe having a high share of people living in differently sized urban agglomerations, the connection between these becomes increasingly important when considering the 4HD2D goal. However, since a lot of air trips are for private reasons, the connection to rural areas or various holiday destinations has to be ensured as well. One of the challenges to achieve the 4HD2D goal is ensuring fast and reliable transport options for the "first and last mile", i.e. those parts of the trip that ensure a true door-to-door travel experience. Moreover, the airport access mode quality is also an important enabler for passenger air travel demand (Bondzio, 1996).

2.5 Socio-economic drivers

2.5.1 Gross domestic product (GDP)

GDP is an essential factor describing our future world, as already explored in previous sections. It is also one of the main drivers for demand in the European air transport market and already examined and discussed within many studies (i.e. Chèze & Chevallier (2011); Dobruszkes et al. (2011); Kopsch (2012); Lyneis (2000) and Pearce (2008)). GDP affects demand positively and can also be used as a proxy for income (Wadud, 2013) and as a factor for comparing living standards between different countries (Eurostat, 2016b). There are several publicly available databases for current GDP data as well as forecasts, such as via Eurostat, IMF, OECD, World Bank and others. Figure 11 depicts the projected GDP per capita for the EU28 and EFTA countries. The milestone years 2035 and 2050 are marked on the x-axis in red. For almost all considered countries, GDP per capita will rise constantly until 2050. Throughout all years, Luxembourg is the country with the highest GDP per capita and Bulgaria and Romania have the lowest values (Frederick S. Pardee Center for International Futures, 2014).

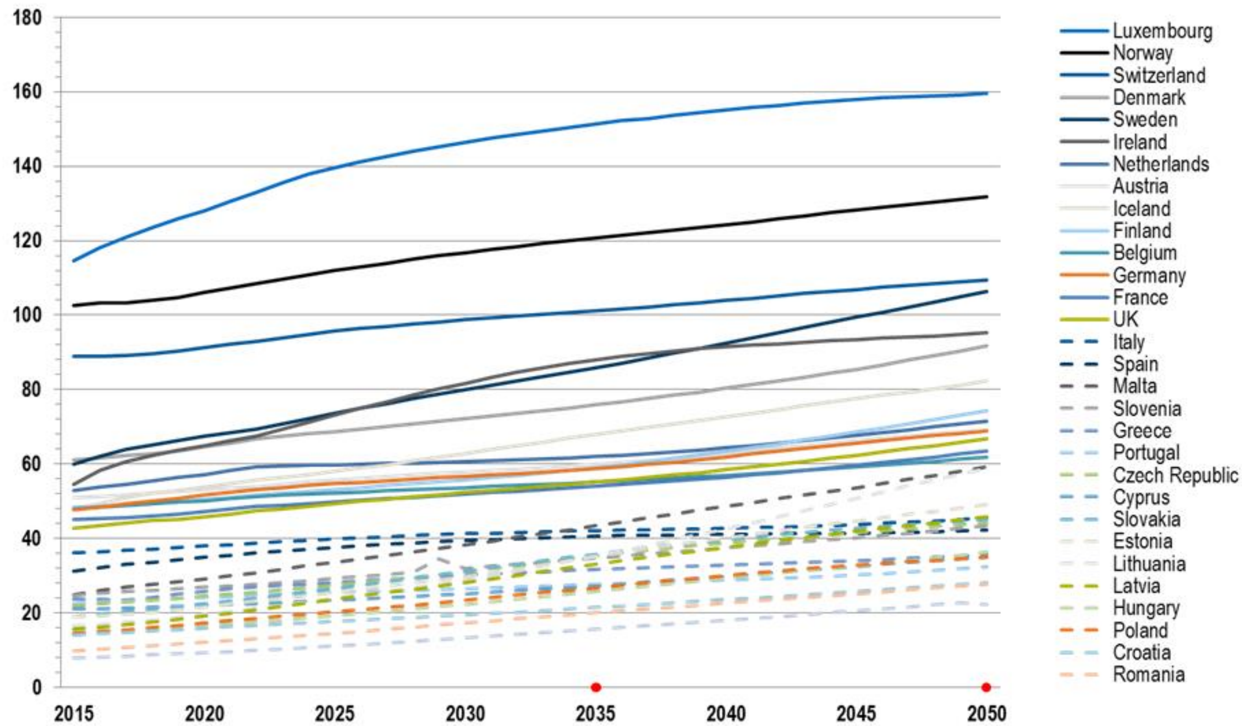

Figure 11: GDP per capita (in thousand US$) EU 28 and EFTA countries[1] (data: ifs, 2014)

This positive GDP development is also underlined by other sources, such as by Pricewaterhousecoopers (PWC). Their long-term global economic growth projection confirms a moderate growth rate of real GDP of around 2 per cent until 2050 for the European Union (EU). According to this analysis, a 2 per cent growth rate is the norm for an advanced economy such as the EU (PWC, 2015). A comparison with other major (advanced and emerging) economies can be seen in Figure 12.

[1] *data for Liechtenstein missing*

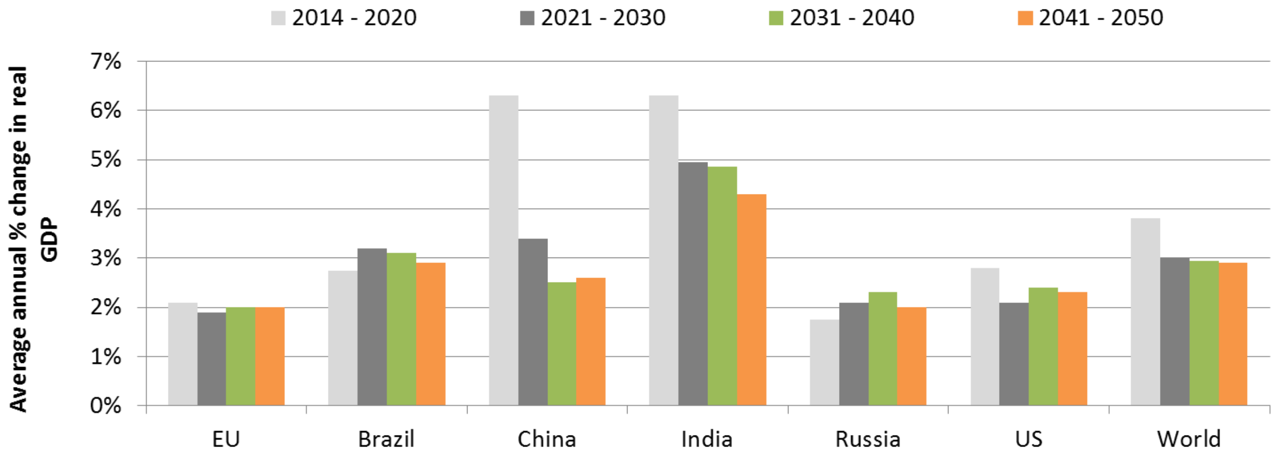

Figure 12: GDP growth for six major economies and the world, year 2014 - 2050 (data: PWC, 2015)

Hence, it can be expected that this positive GDP growth will drive passenger demand positively in 2035 and 2050. Looking specifically at the development of GDP per capita and taking GDP as a proxy for income, people in 2035 and 2050 will probably have a higher income, which might increase the discretionary income spent for holidays and hence possibly increase the travel frequency (IATA, 2016). However, as seen in Figure 11, this development will differ by country and income will be much higher in countries such as Luxembourg, Norway, Iceland and Sweden.

Exogenous factors and global crises can have an impact on the GDP development - both on a country level and European level - and some of these factors might not be foreseeable (PWC, 2015). A recent example is the outcome of the UK referendum ("Brexit") resulting in increased economic uncertainty, which has affected GDP short-term forecasts for the UK as well as for the Euro-area (Goldman Sachs, 2016). Moreover, such events might impact passenger demand directly, as Brexit could also influence outbound and inbound traffic between the UK and the rest of the EU.

2.5.2 Household structure

Another important driver to discuss is the future household compositions as the size of a family and the household structure are relevant factors shaping our future socio-economic world (OECD, 2011). There are several data indicating that the household structure in Europe is going to change, which will influence future passenger demand. On the one hand, households become smaller with fewer children. For 2020, the average number of children per household is predicted to decline both for Eastern and Western Europe, as depicted overleaf. Within both regions, the average number of children per household will drop to 0.5, compared to 1.0 in 1980 in Eastern Europe and around 0.9 in 1980 in Western Europe (Euromonitor International, 2013). There are several reasons for this development: an increasing amount of women in employment; family planning will be delayed; costs of raising a child will increase; and fertility rates will decrease (Euromonitor International, 2013). Although this forecast does only look into 2020, it can be stated that there is a trend towards households with fewer children within Europe. In the long run, this trend will influence household structures and the number of people using transport services. It can also be assumed that households with fewer children have no responsibility to care for a family and, hence, possess a higher discretionary spending and more available leisure time. This could lead into increasing travel activities and holidays, which ultimately drive future passenger demand. The influence of the life stage and family status on travel behaviour has already been examined in some studies, such as Kattiyapornpong (2006). Within this research, the author shows that childless singles and couples travel more.

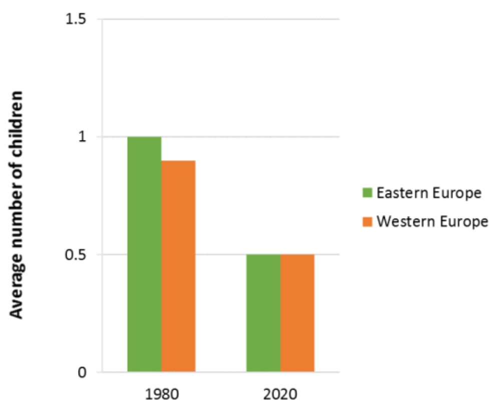

Figure 13: Average children per household in Eastern and Western Europe (data: Euromonitor International, 2013)

In addition, the number of single person households (also known as one person households) is predicted to increase, with this household type having the highest growth index in 2030 worldwide, as depicted in Figure 14 (Euromonitor International, 2014). In Europe, this trend can already be observed. For instance, within the years 2025 to 2030, one person households could already constitute around 40 per cent to 45 per cent of all households in the UK, Austria, Germany, Norway, Switzerland, Netherlands and France, as depicted in Figure 15 (OECD, 2011). One reason for that development is the ageing population (already discussed in a previous section) (OECD, 2011), showing how demographics and household composition can impact each other.

An increasing amount of people living alone also leads to a higher share of single travellers. Moreover, as an illustration from Norwegian consumer expenditure shows, transport is the second largest part of total spending of single person households and thus plays an essential role for people living on their own (Euromonitor International, 2014)[2].

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[2] see appendix for further details (Figure 47)

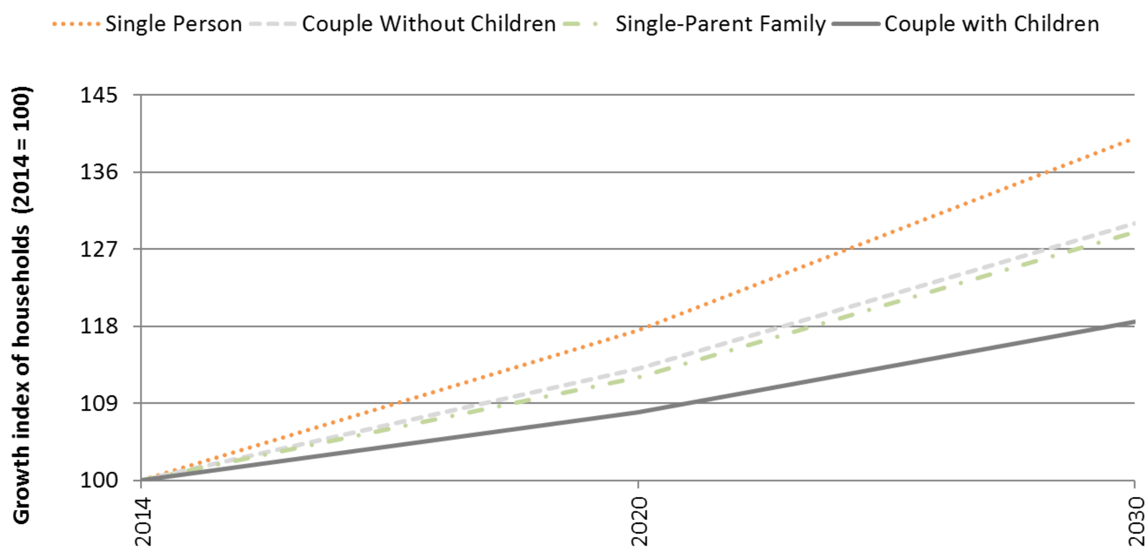

Figure 14: Growth index of households worldwide by type, 2014 - 2030 (data: Euromonitor International, 2014)

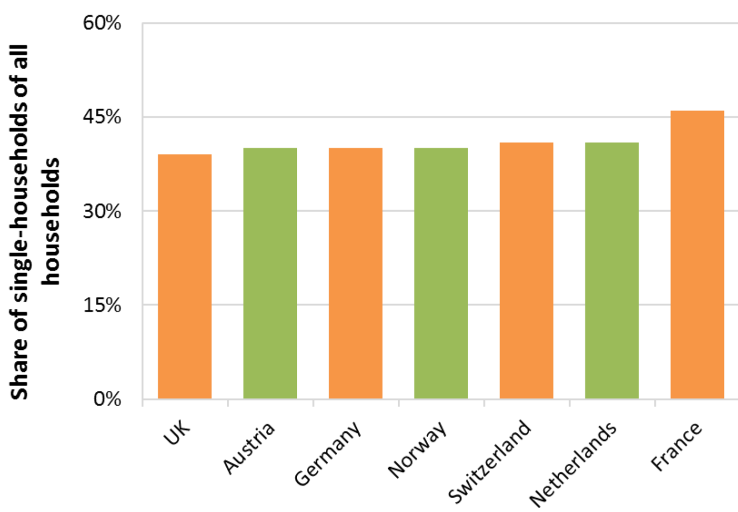

Figure 15: Share of single-households of all households in 2025 - 2030 (data: OECD, 2011)

2.5.3 Education level

Within Europe the tertiary education enrolments are predicted to increase constantly until 2035 and 2050, as depicted in Figure 16, Figure 17 and Figure 18. Western Europe (taken in Figure 17 together with North America) has a much higher volume of enrolments than Central and Eastern Europe. By 2035, 52 million students are projected to be enrolled in North America and Western Europe (Calderon, 2012). On a country level, Ireland, Lithuania and Belgium are the countries with the largest share of population with tertiary education until 2050. Romania, Slovakia and Hungary are predicted to have the lowest share in 2050 (Source: Wittgenstein Centre Data Explorer, 2016).

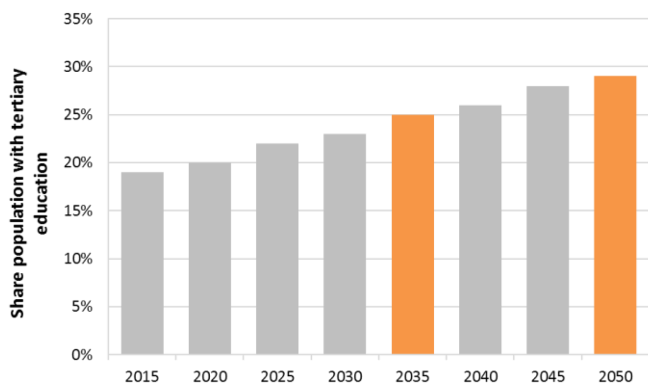

Figure 16: Share of population with tertiary education for EU28 and EFTA countries (data: Wittgenstein Centre Data Explorer, 2016)

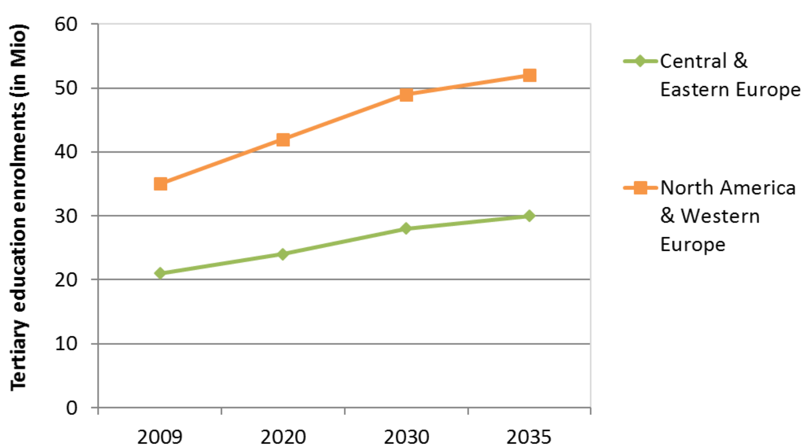

Figure 17: Tertiary education enrolments for 2009 (actuals) and projected to 2035 (data: Calderon, 2012)

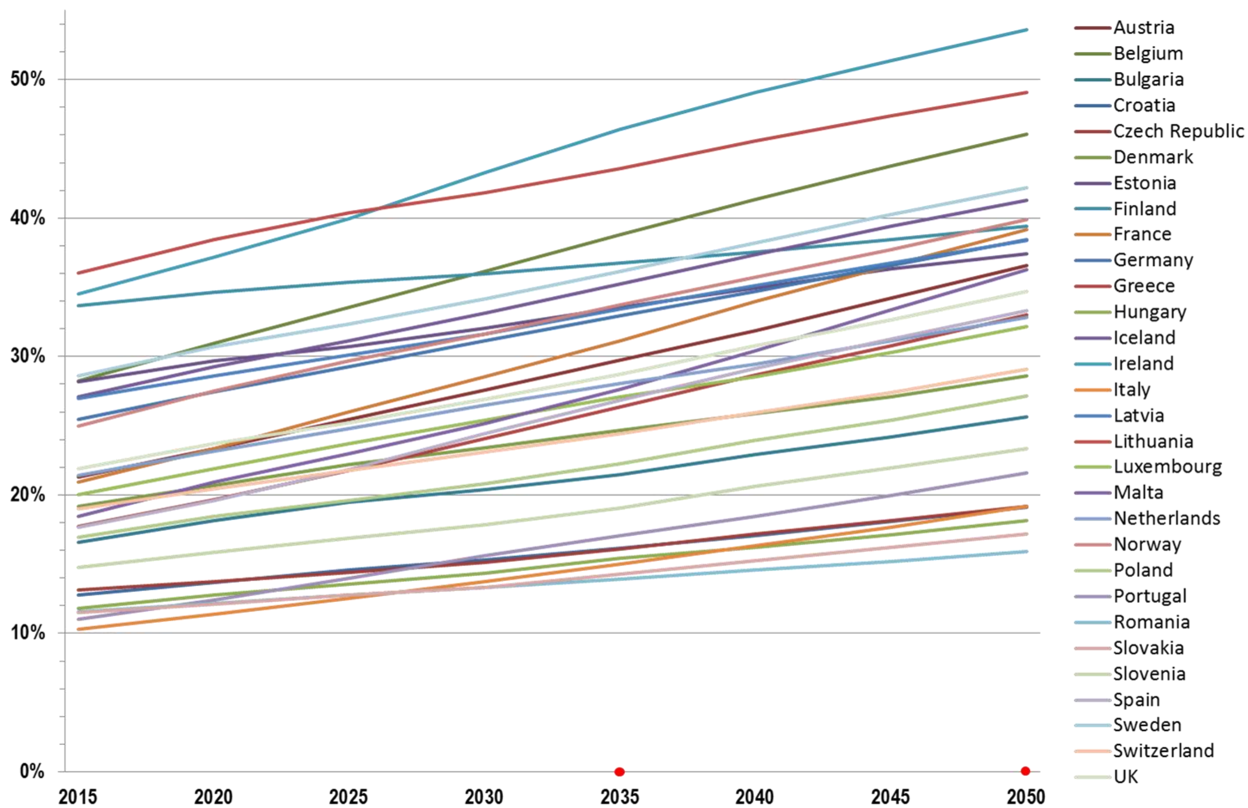

Figure 18: Share of population with tertiary education on country level[3] (data: Wittgenstein Centre Data Explorer, 2016)

A higher educational level often correlates with higher income levels. Education can also influence family planning and hence, household structures as the level of education might delay the age and point in life at which a family is started. As seen in Figure 19, the share of women in tertiary education enrolments will increase for most of the EU28 and EFTA countries until 2025. However, at the same time, so did the childbirth average age in many European countries (OECD, 2011). Women are with a share of almost 60 per cent of enrolments the majority in the higher educational system. A study by the Global Business Travel Association (GBTA) (2011) reveals that 71 per cent of business travellers obtained a college education. Hence, an increase in female tertiary education enrolment could also lead to an increase in working women within higher professions and more women travelling for business purposes.

[3] *data for Cyprus and Liechtenstein missing*

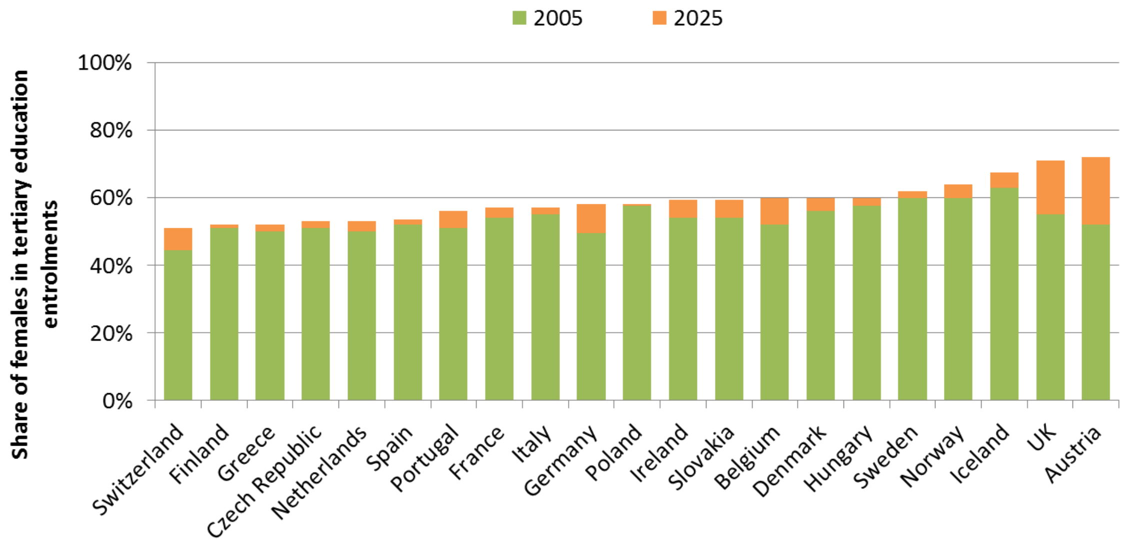

Figure 19: Women in tertiary education enrolments 2005 and projection for 2025[4] (data: OECD, 2008)

2.6 Behavioural drivers

2.6.1 Information and communications technology

ICT has changed the everyday life, both at work and in private, and will continue to do so. There is a rapid development of internet usage bringing many improvements to our future world but also challenges (European Commission, 2016a). The computer literacy rate is going to rise within the next years (OECD, 2011). The internet proliferation will increase: 50 per cent of the worlds' population will have internet access by 2030 (ESPAS, 2015). The internet user penetration in Western Europe in 2019 will be 76 per cent of the total population, indicating that this region has already reached a certain maturity level at this point in time. In comparison, Central and Eastern Europe will reach a penetration level of 64 per cent, over 10 per cent points less compared to Western Europe. Figure 20 and Figure 21 illustrate this development for both regions and selected countries (eMarketer, 2015).

[4] *data available for 21 countries*

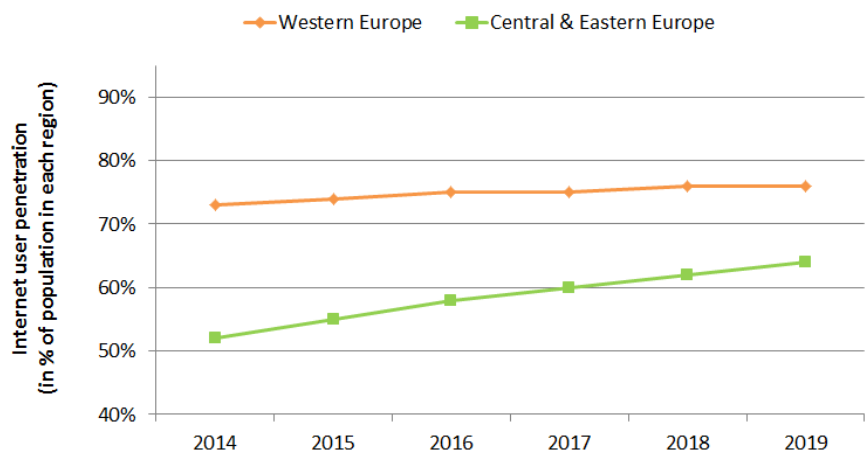

Figure 20: Internet user penetration for Western Europe and Central & Eastern Europe (2014 - 2019)[5] (data: eMarketer, 2015)

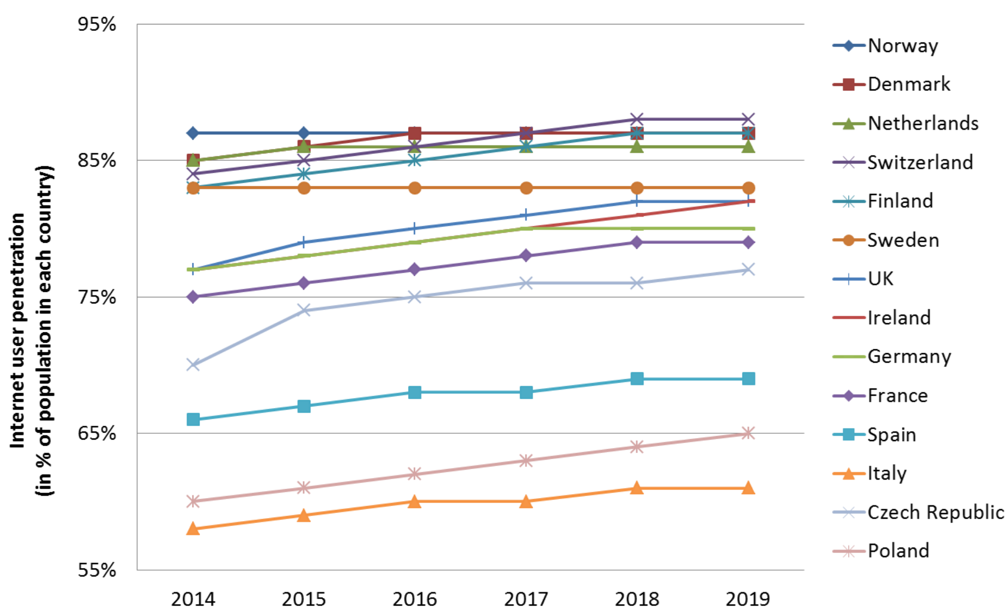

Figure 21: Internet user penetration for 14 European countries[6] (2014 - 2019) (data: eMarketer, 2015)

[5] *individuals of any age who use the internet from any location via any device at least once per month*

[6] *individuals of any age who use the internet from any location via any device at least once per month*

A similar development can be seen when looking at the mobile phone usage in Figure 22. Moreover, the "internet of things" (IoT), big data, cloud computing, 5G mobile internet, smart shoes and smart jackets are among other trends and emerging technologies, digital breakthroughs, which are going to increase until 2030 (ESPAS, 2015; Future Foundation, 2015). By 2020, over 50 per cent of the total population in Western Europe will be active in an online social network, at least once a month (eMarketer, 2016). However, such technological revolutions could also increase privacy issues and create uncertainty and unpredictable impacts on the European society (ESPAS, 2015).

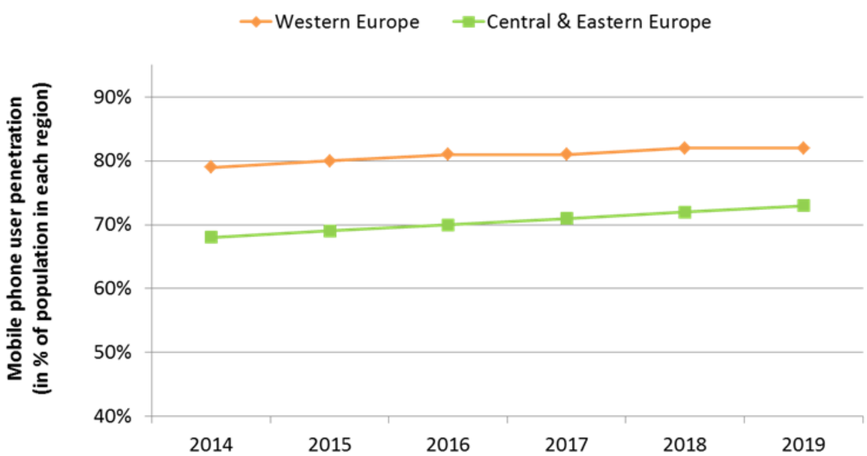

Figure 22: Mobile phone user penetration for Western Europe and Central & Eastern Europe (2014 - 2019)[7] (data: eMarketer, 2015)

As seen within the results of the high-level factor identification, innovation is a very relevant factor when looking into the future world. The usage of the internet, mobile devices, online social networks and emerging technology will increase within the next years, which seem to have been already noticed by some stakeholders in the aviation industry. One example can be found at airports and in their IT strategies. The airport IT survey by SITA (2016) reveals that a large amount of participants are planning mid-term trails concerning new, emerging technologies. For instance, 78 per cent of airports are planning to launch context- and location-aware applications (apps) for passengers until 2026. Passenger benefits from such apps could be a hassle-free journey, time savings and the overall improvement of their travel experience.

[7] *individuals of any age who own at least one mobile phone and use the phone(s) at least once per month*

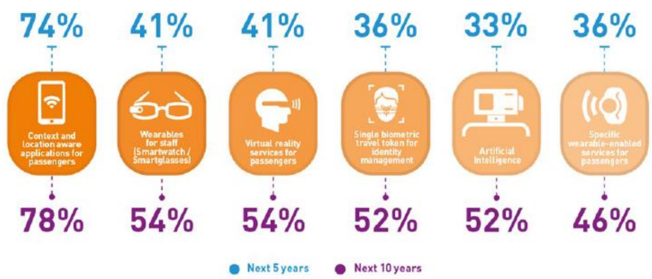

Figure 23: Per cent of airports anticipating piloting the new and emerging technologies (data: SITA, 2016)

As already stated in D3.1 and supported by other sources (i.e. Future Foundation, 2015), the travellers of the future prefer to use own devices for booking as well as preparing flights and - generally - demand to control a high level of their journey on their own and in their own pace. Such travel preferences are supported by the high internet penetration and increasing computer literacy rate, an indication that more and more travellers will feel comfortable using ICT or even demand to do so. This result is not surprising when looking at the digitally savvy generation of Millennials (born in 1980s and 1990s), who will be in their forties and fifties in 2035. Certainly, the generation Z following them will be even more digital natives as they grew up with already advanced technology, deeply embedded into their daily habits and behaviour (Civic Science, 2016).

Finally, emerging technology could also have restraining impacts on the future transport industry. For instance, virtual presence (such as virtual meetings) could be used as a substitute for a journey and therefore decrease the travel demand (Rohr et al., 2016). All in all, ICT and emerging technology will play an essential role for the future transport industry in general and air transport passengers in particular.

2.6.2 Environmental awareness

Generally, consumers have increasing concerns about our environment, the economy and social issues (WBCSD, 2015). One example can be found in Germany, where sustainable consumption and living is as “trendy” as it has never been before. Participating in the sharing economy and buying organic food are high in demand and one could assume an on-going development of this movement within the next years (Die Bundesregierung, 2013). Looking specifically at air transport, passengers also seem to have pro-environmental values and a basic understanding of travel impacting the environment. Yet, future environmental awareness and its influence on passenger demand is a complex topic and difficult to quantify.

Environmental awareness can be driven by many factors and trends. Among others, one potential key driver is education (Bontoux & Bengtsson, 2015). Looking back at section 2.5.3 in this report, we see an increase in tertiary education enrolments within Europe in the next decades, which could also lead to an increase in environmental awareness. However, awareness does not automatically result in pro-environmental behaviour change, such as choosing other transport modes over air transport (especially due to distance reasons for short and medium-haul routes) or paying for carbon offsetting schemes voluntarily. Pro-environmental behaviour change also depends on other factors, like the individual motivation (Steg & Vlek, 2008).

Such factors are, however, difficult to measure. To raise pro-environmental awareness and to trigger a behaviour change until 2035 and 2050, the air transport industry might want to set own incentives and create an environment that supports such behaviour change. Having said that, an increase in passengers' environmental awareness would possibly decrease passenger demand as travellers might substitute air travel by train, coach and other transport modes.

2.6.3 Safety and security

Concerns about the abuse of personal data among all different age groups are already present today. As discussed above, the future passenger will live in an omni-connected world and privacy issues regarding personal data and uncertainty are going to increase (ESPAS, 2015). Looking at several travel scenarios in the UK in 2035, data security and the privacy of passengers are identified as two major drivers for the establishment of emerging technology impacting travelling of the future, such as autonomous vehicles (AVs) and use of Big Data. Thus, until 2035, there will be a strong need for a robust data security system and data privacy regulations created by the government in order to drive those innovations (Rohr et al., 2016).

2.7 Mobility aspects

2.7.1 General overview

Different future developments such as urbanisation, and resulting urban sprawl or increased population density in European cities require a rethinking of current mobility patterns. As outlined in the previous sections and in the parallel report in DATASET2050 on the future of supply within the European transport system (D4.2), a range of drivers are addressed that have an impact on the demand for mobility among European passengers.

In order to obtain a better understanding of the future European transport market, forecasts for the different transport modes, i.e. road, rail, and air, are considered in this section. The following questions will hence be addressed:

1. How much do people travel within Europe in the future in general?
2. What do future mobility patterns look like?
3. How do different future developments influence the demand for air travel?

A shift in transport modes, especially for short-haul routes, can be observed in Figure 24. The use of the car by 20 to 29-year-old people in different European countries has been decreasing since the 1990s. These changing mobility patterns will be transferred throughout their "travel lifetime", i.e. a higher focus will be placed on other transport modes than the private car in the future as well.

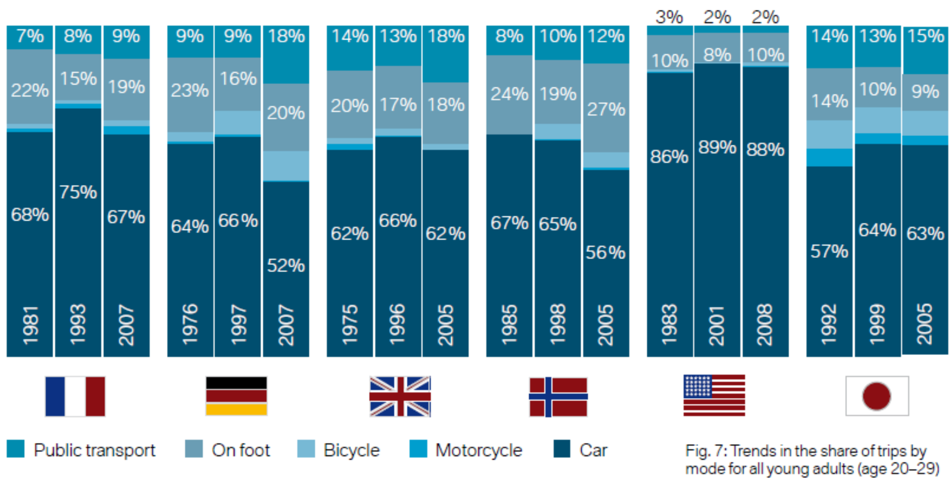

Figure 24: Trends in changing mobility patterns (data: ifmo, 2013)

For the rail sector forecasts show an increase in passenger kilometres up to 2025 (see Figure 25), i.e. rail transport will gain importance across Europe.

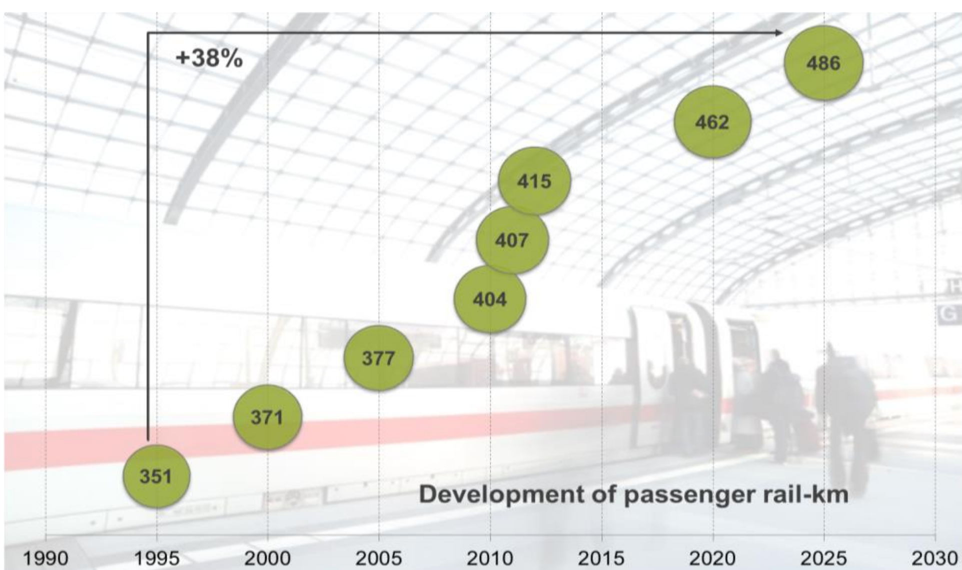

Figure 25: Passenger rail-km (billion) in Europe (data: UNIFE, 2016)

One driver for the predicted increase in passenger rail transport is the investment in rail infrastructure within (Western) Europe up to the year 2025 (Figure 26). Improving existing connections in terms of service quality such as speed as well as opening up new rail connections provides attractive options for passengers within Europe.

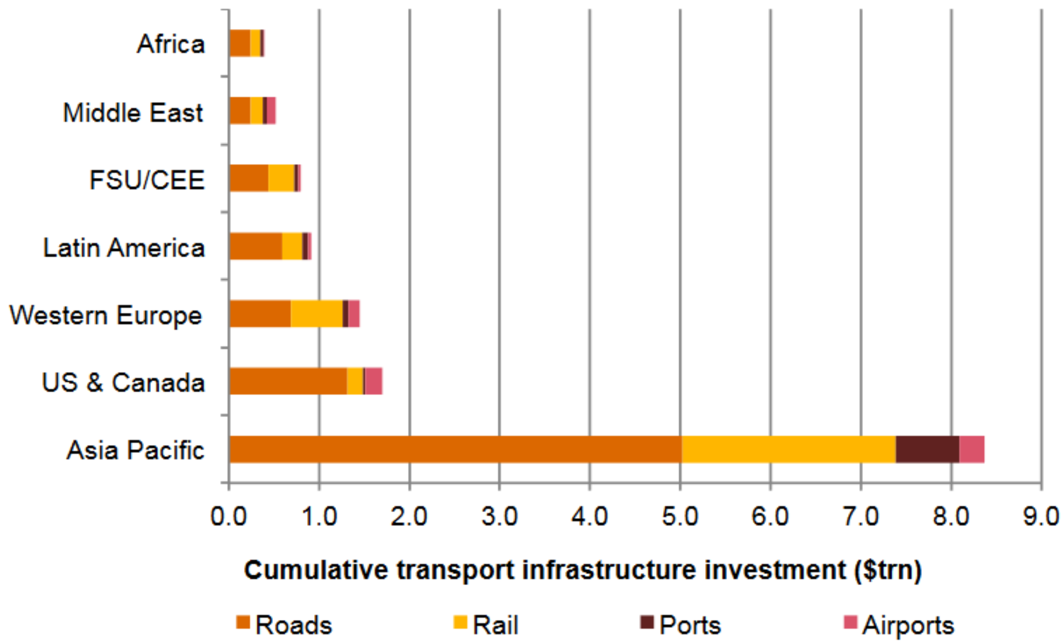

Figure 26: Cumulative infrastructure investment up to 2025 (data: PWC & Oxford Economics, 2015)

The transportation landscape, especially in large urban agglomerations, will experience a shift towards other transportation services compared to what we can observe today. On the one hand, this shift will be towards cleaner and more efficient modes or vehicles, resulting from current and future developments such as urban pollution and rising cost of current energy sources. Furthermore, the landscape of services in the passenger transport sector will develop towards more shared services and less private ownership. Scarce capacities within urban regions push up the price for land and thus parking for private cars, for example. Today's severe road congestion is a result of both increased private car ownership and more people driving alone instead of car-pooling, for example. The car occupancy rate for an European country sample[8] is only 1.45 people per vehicle (European Environment Agency, 2016). In order to achieve time reductions throughout the passenger journey and hence getting closer to the 4 hours door-to-door goal in Europe, shared transport services such as carpooling or mobility on demand (car sharing) are one way to facilitate this. These approaches are also suited to improve the "first and last mile" of a passenger journey; i.e. bridging the last step towards true door-to-door connection (McKerracher et al., 2016).

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[8] *UK, Germany & Netherlands*

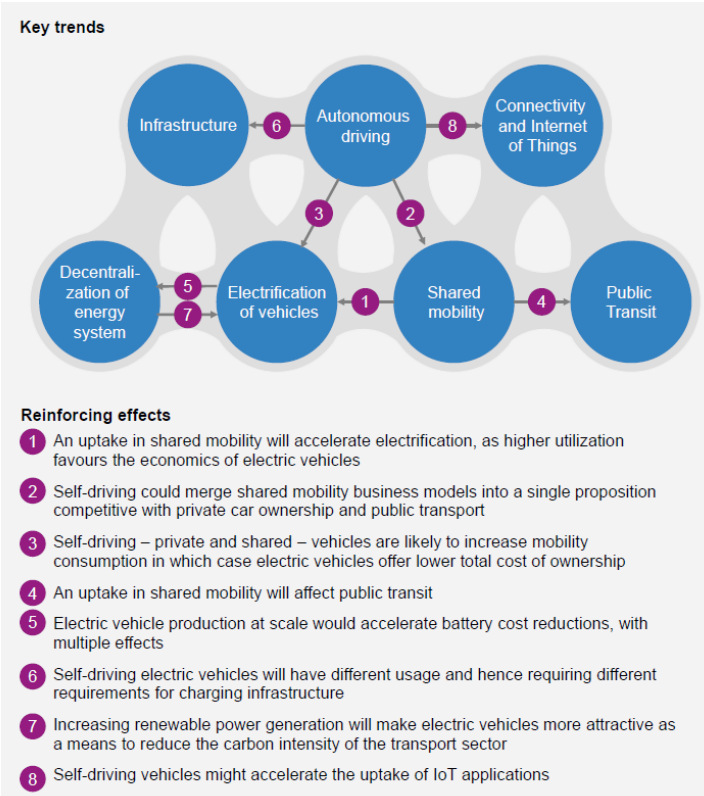

Figure 27: Key trends and reinforcing effects (data: McKerracher et al., 2016)

2.7.2 Air travel

Air traffic development within Europe is predicted to grow in the next 20 to 30 years, however, not at such a fast pace as can be seen in parts of Asia, for example (see Figure 28). Across different air traffic forecasts, the average value regarding air transport development is about 2.8 per cent growth per annum up to the period of 2031 (Figure 28).

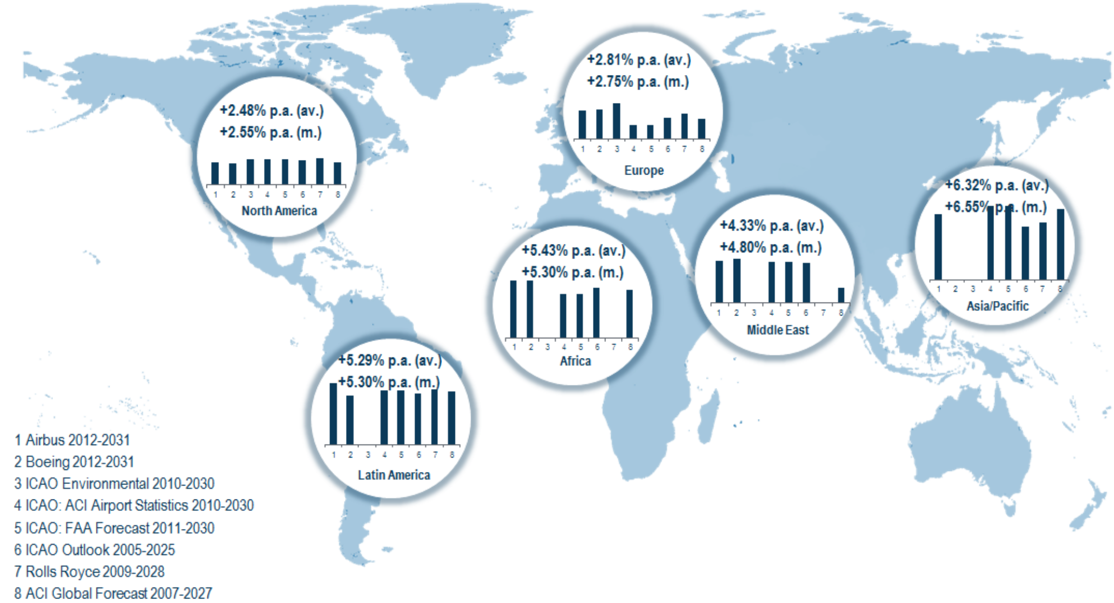

Figure 28: Average domestic RPK growth 2010-2030 (data: own depiction based on several sources)

As outlined in D3.1 and the previous sections within this report, GDP per capita is a major driver of air transport development. The current market forecast by Airbus (2016) illustrates this correlation for China, India, Europe, and North America (see Figure 29). The high amount of trips per capita in Europe and North America also give an indication to some degree of market maturity, which is currently absent in India or China. This means that the potential for air traffic growth is larger in the latter countries. One of the major challenges in Europe as well as in other regions will be the accommodation of future traffic within the existing transport system.

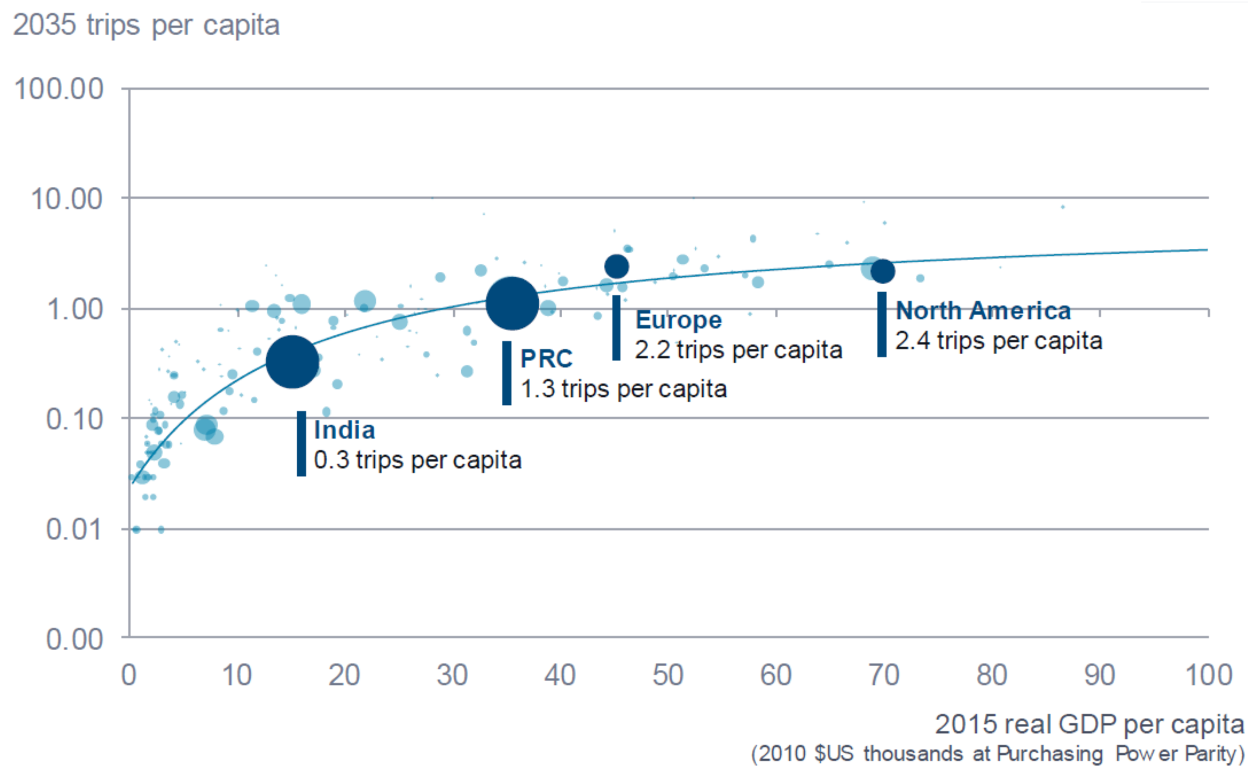

Figure 29: Correlation between number of air trips and GDP (data: Airbus, 2016)

The relationship between GDP and air trips is also investigated by IATA (2014) (Table 1). The results illustrate the average number of air trips by income group as well as the amount of months before a passenger conducts the next trip. These values vary significantly by income group: those within the lowest income group only take an average of 0.04 trips per person and per year whereas people in the highest income group have an average of 1.48 trips.

Table 1: Air trips per capita by income level (data: IATA, 2014)

Income class	Trips per year / person	Months before next trip
Low income	0.04	300
Middle income	0.29	41
High income	1.48	8
Below USD20,000 per person	0.27	44
Above USD20,000 per person	1.80	7

Breaking down the predicted air traffic development across European states yields the picture shown in Figure 30. The report by Eurocontrol (2016) sees the highest growth potential, with more than 4 per cent per annum, in Slovakia, Malta, and Cyprus (of the EU28 and EFTA countries). The lowest growth rates are to be found in Northern Europe - Sweden, Finland, Norway, Denmark, and Latvia - and countries in Western Europe such as Germany and Austria.

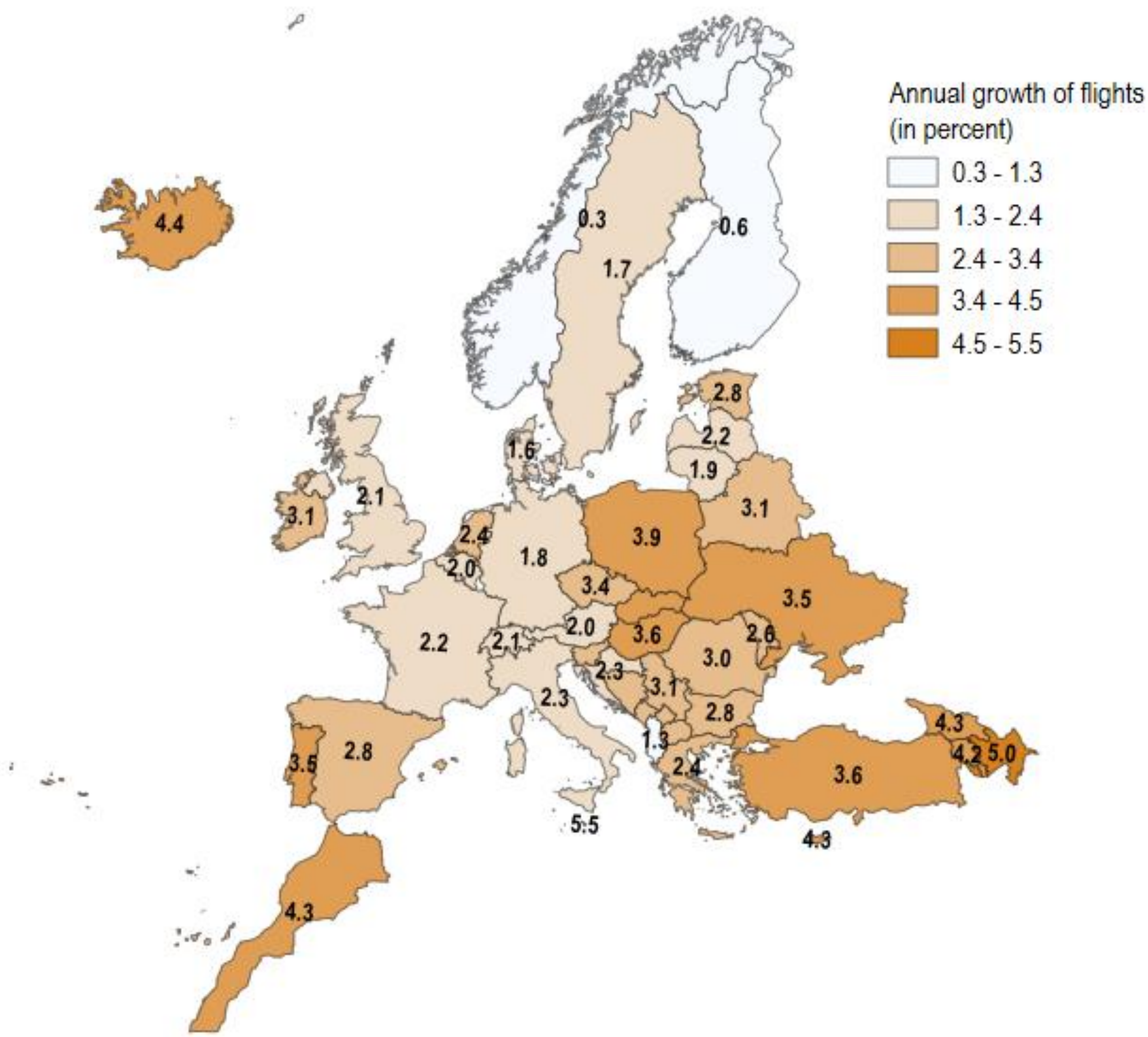

Figure 30: Forecast air traffic development until 2022 in Europe (data: Eurocontrol, 2016)

Hence, current forecasts do not assume a stagnation or even decline in European air transport but a prolonged growth. However, some studies look into demand saturation as well as capacity constraints within Europe and how these will affect both supply and demand of air transport (Wilken, 2016 and Metz et al., 2016). As a result of these developments air traffic might grow less than predicted or even stagnate at a certain level.

2.7.3 (Future) value of travel time

The value of time as described in the previous report (D3.1) is subject to change due to both demand driven as well as supply driven factors. The former relate to changes in socio-economic aspects such as urbanisation, an ageing society, or environmental awareness among (air) passengers. Supply side aspects include the evolution, availability and dissemination of new information and communication technologies as well as emerging technologies affecting different transport modes such as autonomous driving. The following table will highlight potential impacts of the developments outlined within this report as well as in D4.2 on the future value of time. However, only a high-level approach is provided here since a more thorough analysis is requiring detailed modelling of the aspects influencing the value of travel time.

Table 2: Factors impacting value of time (data: several sources)

Factor	Impact on value of travel time	References
Increasing urbanisation	1. Increasing urbanisation can have effects on the value of travel time in different regards: increasing urban congestion, urban sprawl and distance between work and living	
Ageing society and increasing old-age dependency ratio across Europe	1. The value of time may increase with age, depending on i.e. pre-retirement wage rates. 2. Changing trip making behaviour with increasing age, i.e. time of day / season and number of trips per year (during off-season)	Alsnih & Hensher (2003) Möller et al. (2007) Sun & Ng (2009)
GDP per capita (as proxy for income)	1. An increase in income leads to an increase in the value of travel time.	Wardman et al. (2012)
(Increasing) environmental awareness	1. This may evoke a change in perception towards transport, i.e. transport modes are not primarily selected according to their speed and comfort level but according to their overall environmental footprint	Gössling et al. (2009)
Ubiquitous connectivity and increased use of handheld devices (ICT)	1. Omnipresent connectivity of society enables digital communication and interaction and may lead both a decreased need for physical meetings, due to the replacement by virtual conferencing technologies, and to increased demand for transport services due to an increasingly global social network 2. Connectivity during travel allows for access of information, entertainment, or work-related access, hence reducing the value for travel time	Fraunhofer IAO & Horváth & Partners (2016)
Increasing level of tertiary education	1. Development of the service sector, increasing specialisation, hence rise in business travel (see also D3.1 for influence of education on air travel) and resulting increase in value of travel time	ifmo (2014)

Factor	Impact on value of travel time	References
Car sharing	1. Door-to-door on-demand offering can fulfil first- and last-mile transport by connecting remote locations with public transport networks	McKerracher et al. (2016)
Autonomous driving	1. The availability of autonomous cars can lead to an increase in the willingness to pay for in-vehicle services to be used during travel time 2. An SP experiment in the Netherlands shows that passengers exhibit a larger disutility of travel time with automated vehicles than with manually driven ones	Fraunhofer IAO & Horváth & Partners (2016) Yap et al. (2016)

Regarding the future development of **European mobility patterns**, the following findings can be highlighted:

1. **Transport volume** within Europe is predicted to increase further; however, countries with a high level of air transport will face lower growth rates than those with currently low demand for air transport.
2. **Capacity shortages** and the potential for **market maturity** in some European countries are not incorporated in many forecasts but may play an essential role and therefore have to be addressed in future transport systems.
3. **Changing mobility patterns** such as increased car sharing or the dissemination of autonomous cars will have an effect on door-to-door mobility and may provide opportunities to enhancing door-to-door travel times.
4. Future developments, both demand-side (D3.2) and supply-side (D4.2) driven, influence the **future value of travel time**, i.e. lead to a different valuation of the time spent during travel.

2.8 Interim Conclusion

This section has elaborated on prospective developments of demographic, geographical, socio-economic and behavioural factors, as well as mobility aspects, influencing the demand for mobility in general and for air transport in particular with a focus on the years 2035 and 2050. Whereas some outlooks are rather vague, other developments are very well supported by data and several sources. Figure 31 summarises the essential drivers for future passenger demand and the potential developments. On the basis of these results, implications for future passenger profiles will be derived in the next sections.

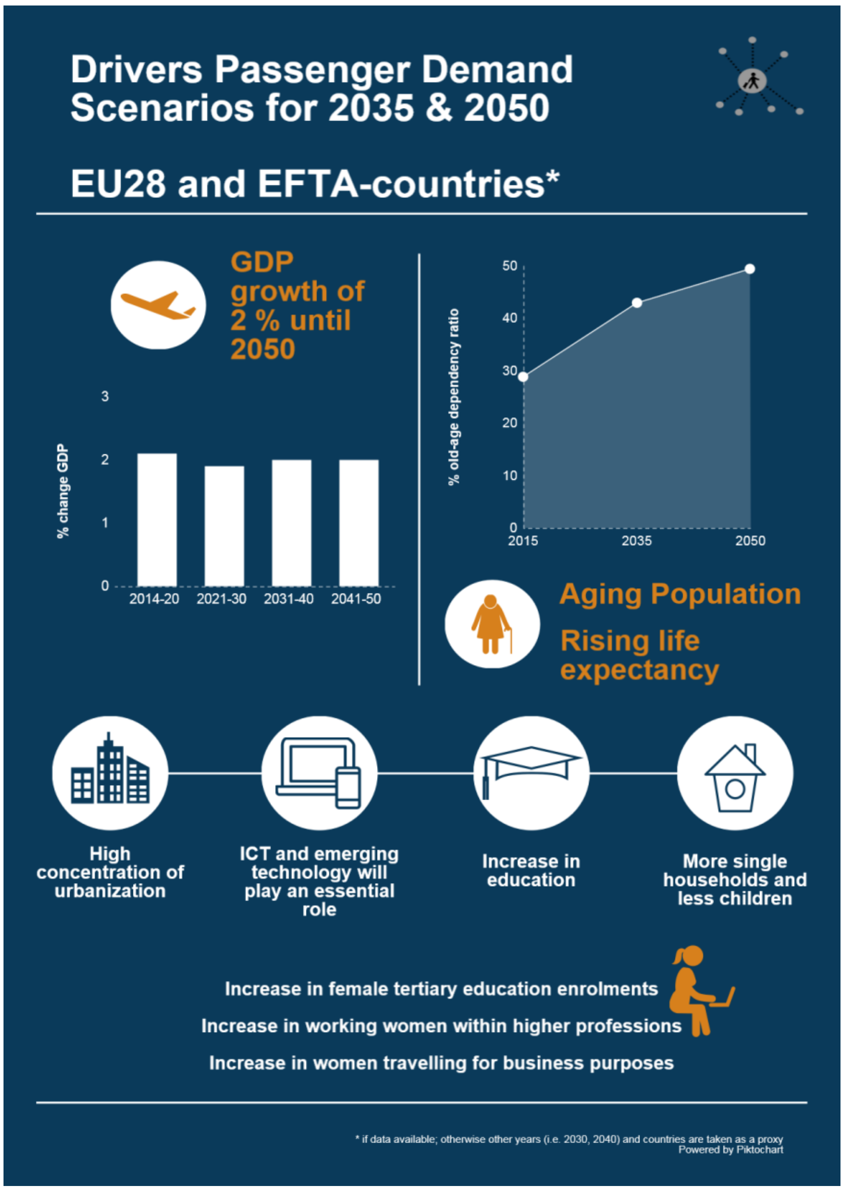

Figure 31: Drivers passenger demand for the years 2035 and 2050 (own depiction)

3 PART TWO: PASSENGER DEMAND MODEL

3.1 Overview

This simulation will be conducted to predict future passenger demand in 2035 and 2050 based on publicly available data in line with the data-driven approach taken in the DATASET2050 project. In doing so, it will be shown how passenger demand is changing within the EU28 and EFTA countries and that it is essential to discuss future passenger profiles in order to get an understanding about the needs and requirements of this important stakeholder group within the air transport system.

At first, a causal loop diagram will identify the relationships and dynamics between factors driving passenger air travel demand. Secondly, the section on the data sources will show where the input factors for the model are coming from. After elaborating on the general structure of the model, the modelled results for 2035 and 2050 will be presented, showing the passenger air travel demand for these two years. A brief discussion of the results and limitations will conclude this section.

3.2 Passenger demand model

3.2.1 Causal loop diagram

The previous section has elaborated on the future development of external factors driving passenger air travel demand. These aspects are not just driving demand but are also interrelated and influence each other. To identify these relationships among them and to have a graphical representation at hand (overleaf), a causal loop diagram was drawn as seen in Figure 34. Each factor is depicted as a variable. The directions of the blue and green lines between the variables and the plus and minus signs indicate the relationship between the different factors, i.e. the arrows at the end of each line depict in which direction the factors influence each other. The + sign shows that change (such as an increase or decrease) in factor A will trigger the same direction of change (increase or decrease) in factor B. The - sign refers to the opposite effect. A brief explanation and two examples can be found in Figure 32.

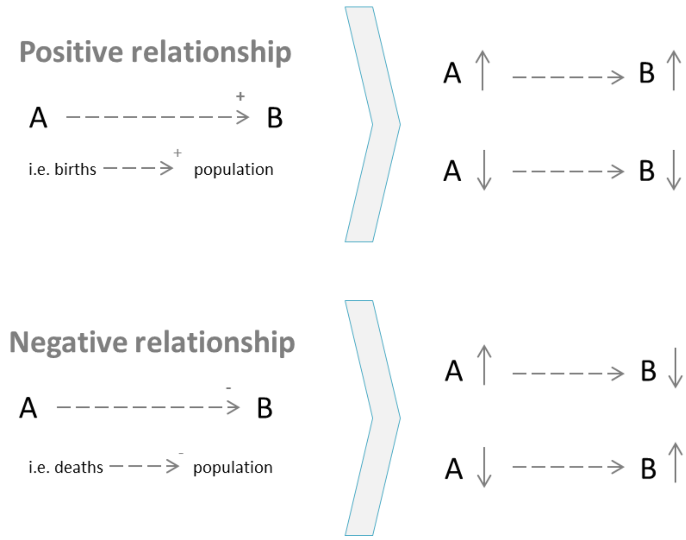

Figure 32: Positive and negative relationship in causal loop diagram (data: Gracia, 2006)

Moreover, the relationship between the factors can be closed like a chain. These relationship chains are called feedback loops and several can be found within the causal loop diagram. These feedback loops characterise the structure of the depicted system and describe how the factors affect each other. A loop can be negative, also known as balancing as they have the tendency to stabilise the system, or positive, also known as reinforcing with a tendency to destabilise a system and to generate growth. Such (balancing or reinforcing) polarity provides an indication for the causality direction. Additionally, the feedback loop is either clockwise or anticlockwise, providing a hint to which direction the loop is directed and has to be read (Garcia, 2006; Sterman, 2000).

An overview of all feedback loops can be found in the appendix (see Figure 48). One of the main reinforcing feedback loops is depicted in Figure 33 and will help to understand the theory. An increase in *Passenger_Air_Travel_Demand* results in an increase in *GDP_Growth* (positive relationship). An increase in *GDP_Growth* increases *Income* (positive relationship). An increase in *Income* results into a higher *Education_Level* (positive relationship). The *Education_Level* increases in line with *Women_in_tertiary_Enrolments* (positive relationship). An increase in *Women_in_teriary_Enrolments* will lead to more women pursuing a career and results in an increase in the number of *working_Women* (positive relationship). This will result in planning a family at a later stage in life and hence an increase in *Childbirth_Age* (positive relationship). An increase in the *Childbirth_Age* results in fewer *Children_per_Household* (negative relationship). Due to singles' having a higher disposable income and hence spending more on (air) transport and vacations, fewer *Children_per_Household* will result in higher *Passenger_Air_Travel_Demand* (negative relationship).

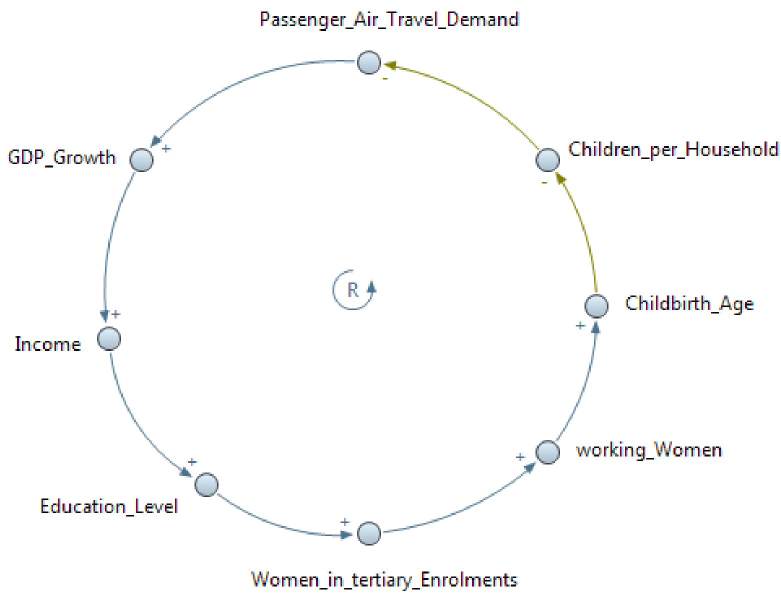

Figure 33: Example reinforcing feedback loop (own depiction)

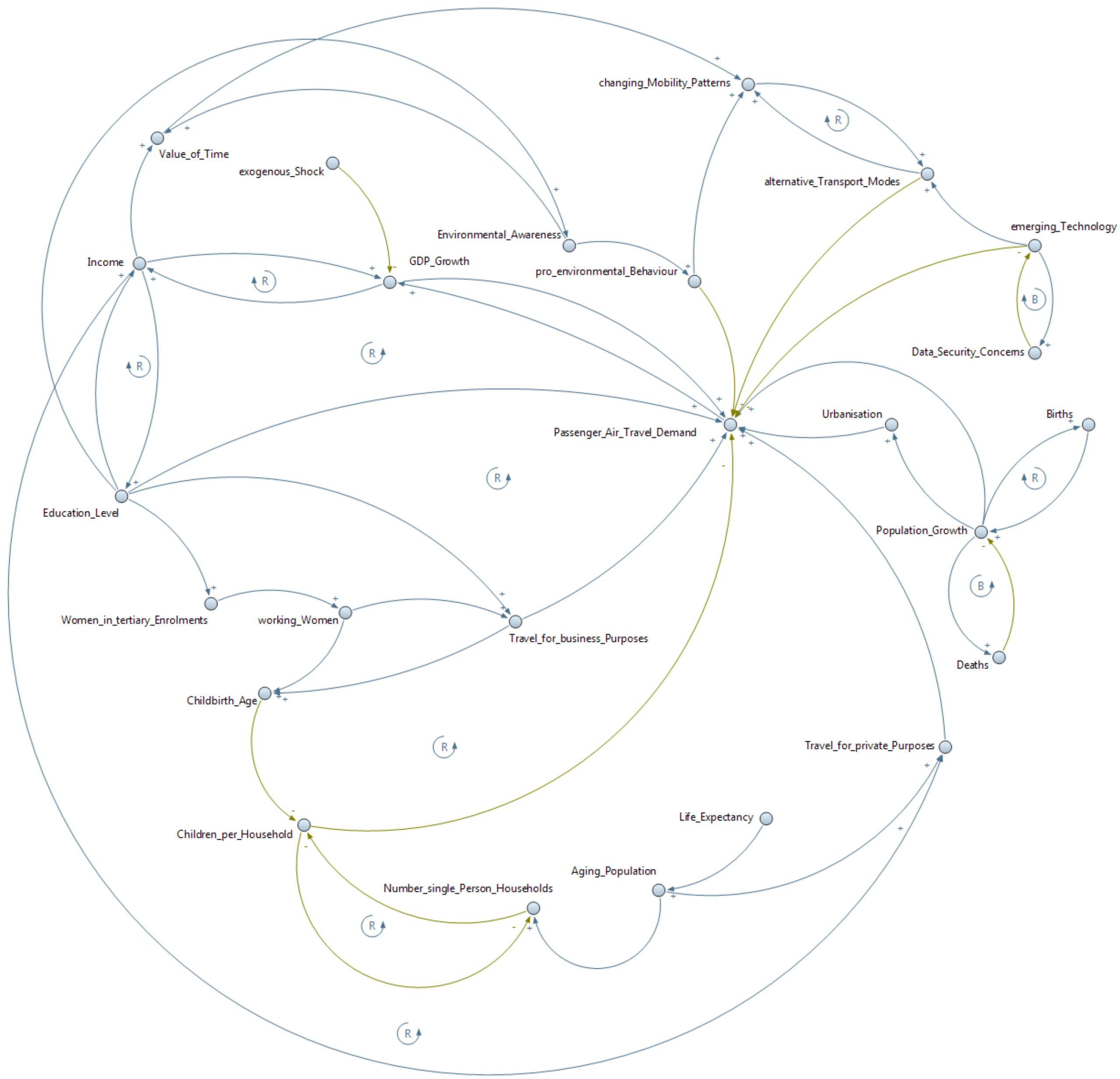

Figure 34: Causal loop diagram (own depiction based on previous sections and Suryani et al. (2010))

3.2.2 Data sources

The next step is to build a model for passenger air travel demand with historical and forecast data. Two factors are used to demonstrate the relationship between drivers and passenger air travel demand. These factors are selected because of lack of data for other factors as well as their strong relevance for driving passenger demand as already discussed in the previous sections.

GDP is one of the main drivers for passenger air travel demand. Within the model, how GDP growth will drive demand for the considered country set until 2050 will be explored. As data input, the historical and projected growth rate per year of real GDP for the years 2012 to 2050 are used, taken from several data sources (Eurostat, 2016c; European Commission, 2016b; PWC, 2015). The growth rate is measured in per cent and defined as the change in real GDP compared with the previous year.

Moreover, as explored in the previous sections and seen in the causal loop diagram, education seems to be one of the key factors within the system. Hence, it is also used as a driver here. The share of population with tertiary education for EU28 and EFTA countries[9] is obtained from Wittgenstein Centre Data Explorer (2016) for the years 2012 to 2050. Data is provided in 5 year steps. For both time series linear interpolation is assumed to get the growth rate for each year within the respective 5 year time span. Passenger air travel demand for the starting year 2012 is measured in passenger traffic volumes for the considered country set. Numbers include total passengers, scheduled and non-scheduled including direct transits[10] (ACI, 2012). All used variables and respective data sources are summarised in Table 3. Further details can be found in the appendix in Table 7 and Table 8.

Table 3: Data basis demand model (own depiction)

Real GDP growth rate (2012 – 2015)	Eurostat statistics (2016c)
Real GDP growth rate (2016 – 2017)	European Commission Forecast (2016b)
Real GDP growth rate (2018 – 2050)	PWC analysis (2015)
Tertiary education growth rate (2012 – 2050)	Wittgenstein Centre Data Explorer (2016)
Passenger traffic volumes (2012)	ACI (2012)

A regression analysis was conducted to address whether factors like GDP, urbanisation, level of education, age structure and the geography (in case country is an island) have a statistically significant influence on air traffic levels in the EU28 and EFTA countries. Results from the regression analysis reveal that geography, level of education and GDP are statistically significant (Kluge et al., 2017). All continuous variables have been logged, i.e. all variables apart from geography and hence, the coefficients can be used as the estimated elasticity in the model for the two factors above (Wooldridge, 2006). They imply that a 1 per cent increase in GDP and the level of education increases

[9] *data for Cyprus and Liechtenstein missing*

[10] *data for Liechtenstein and Slovenia missing*

air travel demand by 1.525 per cent and 1.296 per cent[11]. As not all countries from the EU28 and EFTA countries are islands, geography is not included in the demand model. However, as seen in the results of the regression analysis, this factor has a significant influence on demand.

The model is designed to run on a yearly basis, starting in 2012 and ending in 2050. For the implementation, the simulation tool AnyLogic and a system dynamic approach is used.

3.2.3 Scenario 2035 and 2050

The demand model is built using stocks, flows, parameters and variables. A brief explanation of these is given in Figure 36. The *yearlyGdpGrowth* rate and the *tertiaryEducationShareGrowth* rate are both variables. For every year, each growth rate is multiplied by the respective elasticity and subsequently feeds the flow *rateofDemandChange*. The *rateofDemandChange* feeds the stock *PassengerTrafficVolumes* as an inflow. A parameter provides the initial value of passenger traffic volume for 2012, 1 384 099 000 passengers. The model is depicted in Figure 35.

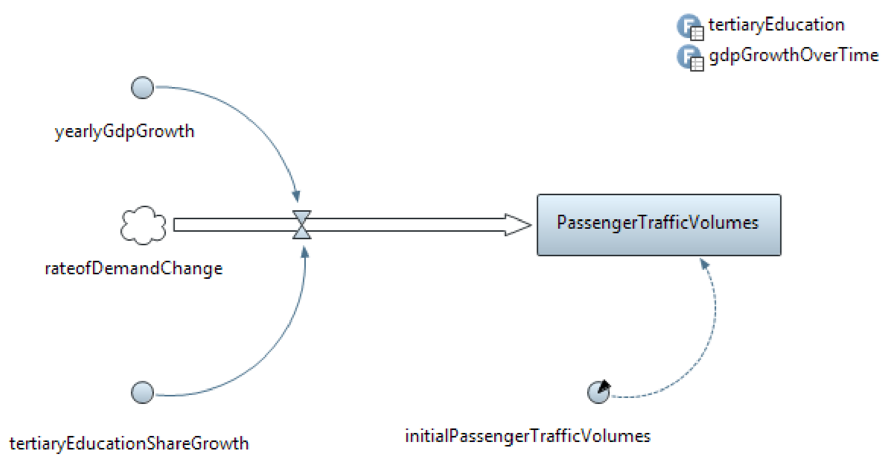

Figure 35: Passenger demand model (own depiction)

[11] *BCG (2006) shows a similar GDP elasticity in respect to passenger growth of 1.7 for international passengers from 1995 to 2000 (calculated taking the change in passenger growth (in CAGR) divided by the change in the real GDP growth). Taking GDP as proxy for income, similar values can be found in other studies. For instance, for developed economies such as the EU28 and EFTA countries, IATA (2008) estimated an income elasticity of air passenger demand from 1.3 to 1.6 (for short- and medium-haul flights). The Department for Transport (2013) calculated an income elasticity of overall 1.3 for the UK.*

Stock	*"Stocks are accumulations, and characterize the state of the system."'* (Borshchev, 2013, p. 41)
Flow	*"Flows are the rates at which these system states change."* (Borshchev, 2013, p. 41)
Parameter	*"[...] parameters and "constant" variables, which serve as inputs [...]"* (Borshchev, 2013, p. 197)
Dynamic variable	*„Variables are generally used to store the results of model simulation or to model some characteristics of objects, changing over time."* *(AnyLogic Help, 2016)*
Table function	*"Table function is a function defined in the table form. The user defines a function by providing several (argument, value) pairs, [...]"* (Grigoryev, 2016, p. 129)
Loop balancing	*"balancing loops have an uneven number of negative links."* (Grigoryev, 2016, p. 115)
Loop reinforcing	*"reinforcing loops have an even number of negative links (zero is also even)."* (Grigoryev, 2016, p. 115)
Link	*"[...] graphically define dependencies among a stock and flow diagram's elements."* (Grigoryev, 2016, p. 110)

Figure 36: Causal loop diagram and passenger demand model explanation (own depiction)

Due to a decreasing GDP in 2012, demand growth is negative in the first modelled years. After that, both for 2035 and 2050 the demand is positively influenced by the drivers as can be seen in the time plot in Figure 37. From 2035 onwards, demand grows constantly at a rate around 3.5 per cent per year, only based on *yearlyGdpGrowth* and *tertiaryEducationShareGrowth*.

Looking back at the causal loop diagram, it can be seen that these two drivers do not just influence demand but also each other. *GDP_Growth* increases *Income* and an increase in *Income* results in a higher *Education_Level*.

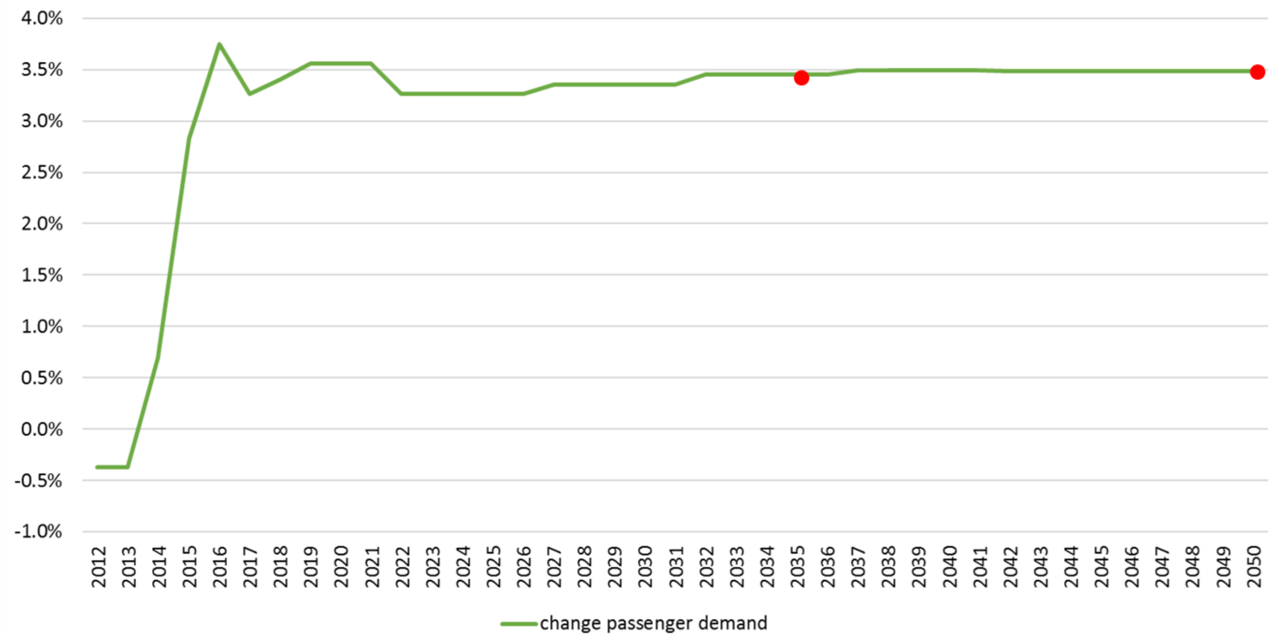

Figure 37: Time plot: change of demand until 2050 in per cent and per year (own depiction)

3.3 Limitations

As with every model, there are limitations. Passenger growth is expected to have a higher yearly growth rate within developing regions like Eastern Europe (Airbus, 2016). Such regional differences are not depicted in the model as all countries from the EU28 and EFTA country set are taken together. To verify this development, the demand model would need to be run on country-based data, also allowing geography to be included as another demand driver for island countries.

Due to limited publicly available data, only two drivers have been modelled and it is difficult to compare the results with other, more comprehensive forecasts (which, for instance, comprise more demand drivers due to enhanced data access). No internal demand drivers are taken into account and as studies show, some of these might decrease air travel demand. For instance, a negative elasticity has been found for price elasticity in respect to passenger demand (IATA, 2008).

Moreover, other contextual factors, such as the distinction between short-haul, medium-haul and long-haul or – as used in a study by the Department for Transport (2013) – market maturity and behavioural changes of the passenger, are not included either.

4 PASSENGER PROFILES IN 2035

4.1 Derivation of future passenger profiles

To identify effects of changing passenger characteristics and related (air) travel behaviour as well as resulting shifts in passenger segmentation in the demand profiles for 2035 and 2050, several steps have to be taken. This process is described and depicted below.

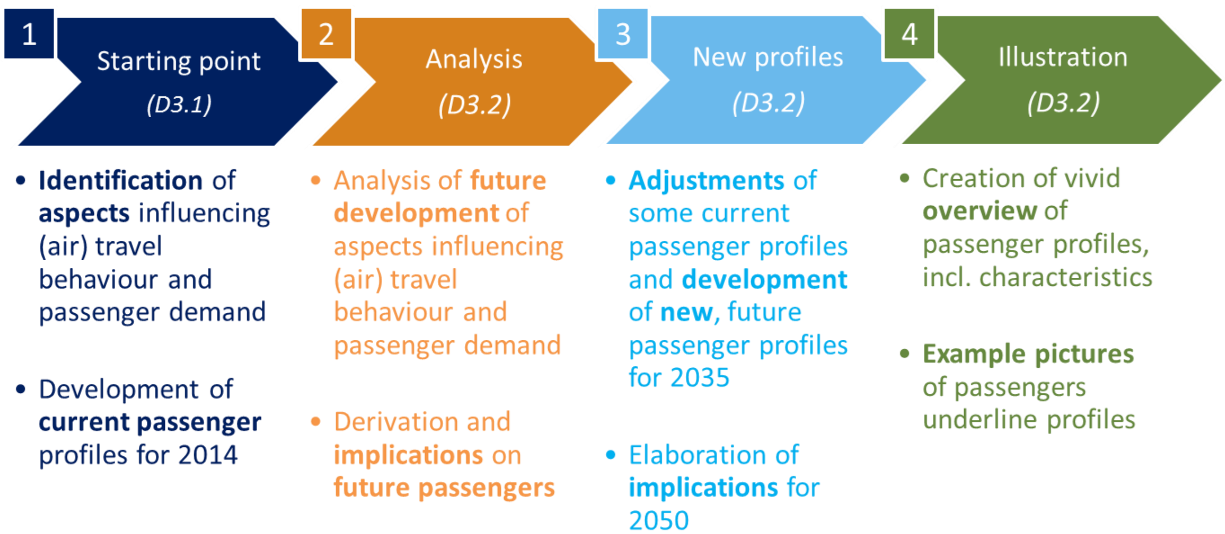

Figure 38: Process development of future passenger demand profiles (own depiction)

1. **Starting point of the derivation**
   Before looking into future demand profiles, one has to be aware of the current passenger situation. Therefore, as a first step, demographical, geographical, socio-economic, behavioural and mobility aspects influencing European (air) travel behaviour and demand are identified and described. Based on these data, current passenger demand profiles are derived. Existing studies on passenger profiles are also taken into account as a second source. As a result, six profiles have been developed. This work was carried out in D3.1

2. **Analysis of future development**
   In the second step, the previously identified aspects described above are analysed with respect to their future development and outlooks for 2035 and 2050 (when data available). Where possible, the analysis focuses on European data. Results from the high-level factor identification taken from D4.2 are also integrated into this step.

Table 4: Factors driving future passenger profiles (own depiction)

	Cultural Seeker	Family and Holiday Traveller	Single Traveller	Best Agers (Next Generation)	Environmental Traveller	Digital Native Business Traveller
Overall population growth	x	x	x	x	x	x
Ageing population	x		x	x		
Rise of average life expectancy	x		x	x		
Urbanisation	x				x	x
GDP growth (as proxy for income)	x	x	x	x		x
Fewer children per household	x	x	x			x
Smaller households	x		x			
Tertiary education					x	x
Internet and mobile phone proliferation	x					x
Environmental awareness					x	
Propensity to fly	x	x				x

3. **Development of new passenger demand profiles**
   Thirdly, to develop new passenger demand profiles, the current ones are either adjusted, or new profiles are created on the basis of available data. As there is still a lot of uncertainty regarding how we are going to travel in the future, and since the DATASET2050 project follows a data-driven approach, only passenger characteristics that can be supported by data are taken into consideration. Examples for developments supported by data are the ageing population in

Europe, the increase in single households and the tendency to have fewer children per household. Therefore, some characteristics from current profiles cannot be found in the future profiles but all characteristics within the future profiles are supported with sources. The main drivers of each profile can be found in Table 4. For 2035, six future passenger profiles for the EU28 and EFTA countries are developed. For 2050, the report elaborates on general implications for (air) transport passengers. The results of this step are presented in the next section. A short description of all future profiles and an explanation of the icons used in the profile overviews can be found in the appendix.

4. **Illustration of new passenger demand profiles**
   To present the profiles in a vivid manner, profile overviews - illustrated with exemplary photos - are developed. These can also be found in the next section. All steps described above are also summarised in Figure 38.

   It must be mentioned that one person is not necessarily assigned to only one profile. Depending on the context, passenger characteristics change. For instance, a person travelling for business purposes (short dwell-time at the airport, business class, hand luggage only etc.) belongs to a different profile than when travelling for leisure with spouse and children (longer dwell-time at the airport, economy class, more luggage to check in etc.). Still it can be the same person, only within a different travel context.

4.2 Profiles for 2035 (and 2050)

4.2.1 Cultural Seeker

The *Cultural Seeker* is a newly developed passenger profile but has similarities with the *Exclusive Experience Traveller* from the current passenger profiles. Typically, passengers are between 15 and 65 years old, covering a large range of people in Europe. His or her main travel purpose is for private reasons. This passenger type travels to cities; into the country side or to specific events for broaden the personal horizon. Taking around 0.5 to 1.5 trips per capita per year, he or she travels as often as the *Family and Holiday Traveller* and as the *Digital Native Business Traveller*. The income level is medium to high, indicating either a financially stable family background or a good education and a well-paid job. The amount spent for transport expenditure is medium to low. Travelling with one or two people, the cultural seeker takes only hand luggage for short trips but checks in luggage for longer journeys. Public transport, taxi and car sharing are the access mode choices to and from the airport (door-to-kerb (D2K); kerb-to-door (K2D)).

Figure 39: Overview "Cultural Seeker" (own depiction)

4.2.2 Family and Holiday Traveller

The *Family and Holiday Traveller* is already part of the current passenger profiles within D3.1. However, in comparison to the current status, the future *Family and Holiday Traveller* in 2035 will be a few years older. As the childbirth age rises, so will the predominant age group for this passenger type: from 24 to 44 years in the current profiles up to 30 to 50 years in 2035. This age range includes children below 15 years, as children older than 15 might have the tendency to take trips on their own or with friends.

This profile travels for private purposes, has a medium to high income and spends a medium amount of that income on transport. Passengers of this type use technical devices with a medium frequency and conduct 0.5 to 1.5 trips per capita per year. As they often travel with children, their party size is around two to three people. Normally, they go on family trips for several days and hence, have the tendency to almost always check in their luggage. They use public transport or the own car (park & fly) to travel to and from the airport (D2K, K2D). Travelling with children, they may also be likely to arrive early at the airport to have more dwell time.

Figure 40: Overview "Family and Holiday Traveller" (own depiction)

4.2.3 Single Traveller

European households are becoming smaller with fewer children and the number of one-person households is going to increase towards 2035. Hence, the *Single Traveller* taking a journey alone will be an important passenger group in 2035. This passenger type travels on his or her own for private purposes and is around 44 years old or older. In comparison to the *Cultural Seeker*, this passenger type has a medium to low income. Spending only a low amount on transport, 0.25 to 0.5 trips per capita are taken per year. Compared with the other passenger profiles, the *Single Traveller* has the lowest travel activity.

As an airport access mode, the *Single Traveller* chooses either public transport or kiss & fly (D2K, K2D). He or she travels with hand luggage when going on short trips but checks in luggage for longer journeys. As long as single travellers arrive and depart on their own, they can be part of a travel group of several people organised by a tour operator.

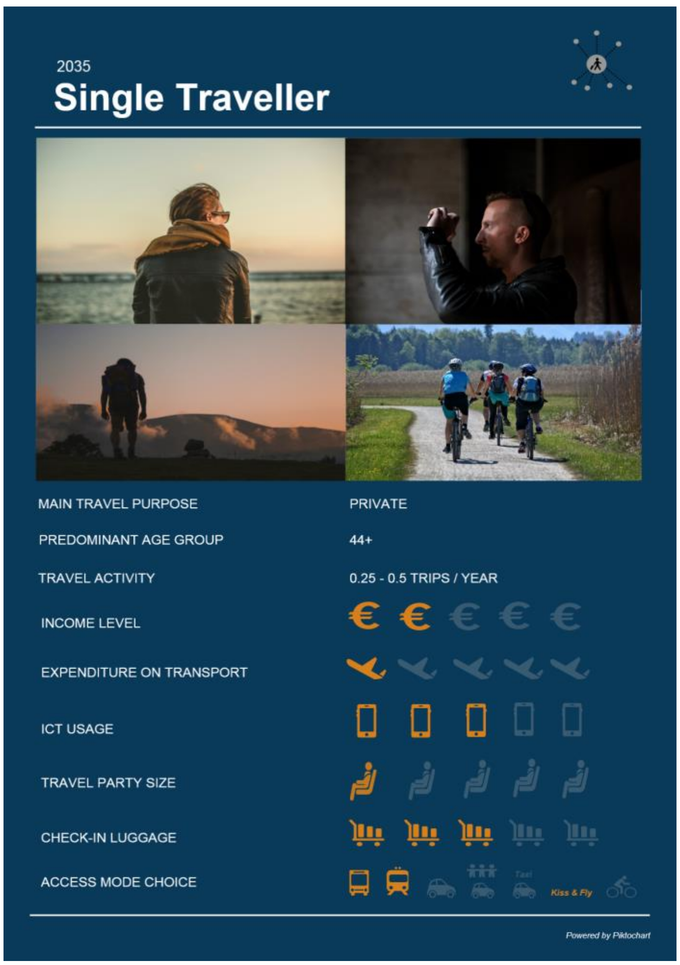

Figure 41: Overview "Single Traveller" (own depiction)

4.2.4 Best Agers (Next Generation)

The group of people with a typical age of 65 years or older will comprise around 25 per cent of the overall European population in 2035. Thus, the *Best Agers (Next Generation)* (in the following only referred to *Best Agers*) are going to be an important passenger group. The *Best Agers* travel around 0.5 times per year. Most people in this age are retired or about to retire within the next years. Hence, these passengers travel solely for private reasons either alone or with another person. They have a medium income and spend a medium amount on transport.

Their use of technical devices is medium as well. In comparison to the *Best Agers* from the current passenger profiles in D3.1, the next generation in 2035 is much more digital savvy. They prefer to check in their luggage and to use their own car as an airport access mode. Alternatively, friends and relatives take them to the airport or pick them up (kiss & fly) (D2K, K2D).

Figure 42: Overview "Best Agers" (Next Generation) (own depiction)

4.2.5 Environmental Traveller

The *Environmental Traveller* is a newly generated passenger profile in 2035. He or she tries to live as environmentally friendly as possible. Part of such lifestyle is to reduce air travel and to fly with as little luggage as possible. This passenger type is typically between 30 and 44 years old, has a medium income and spends little on transport costs. In line with an environment-friendly behaviour, most business trips are combined with some additional leisure time (= bleisure). They might be willing to pay for a carbon offset scheme to compensate their own air journey.

The use of technical devices is low to medium. The travel party size is one to two people, if a friend or spouse is being taken on a bleisure trip to spend the free time together. If really necessary, luggage is checked in. Otherwise, hand luggage is the norm. Every environment-friendly airport access mode is possible, such as public transport, car sharing or cycling (D2K, K2D).

Figure 43: Overview "Environmental Traveller" (own depiction)

4.2.6 Digital Native Business Traveller

The *Digital Native Business Traveller* is the only passenger type of all six profiles who travels mainly for occupational reasons. However, due to the high usage of technological devices one can assume that this passenger type is hyper connected and that there is a constant digital connection with the private life, friends and family.

The *Digital Native Business Traveller* is around 24 to 64 years old, which is at present the digital savvy generation Y and generation Z. The income level and transport expenditure is medium to high. 0.5 to 1.5 trips per capita per year are taken with one to two people. A high share of this passenger type will be female as the increase in female tertiary education enrolment might lead to an increase in working women within higher professions and more women travelling for business purposes. This passenger type does not mind checking in luggage but takes only hand luggage when going on short trips. Public transport, taxi or car sharing are the airport access mode choices (D2K, K2D).

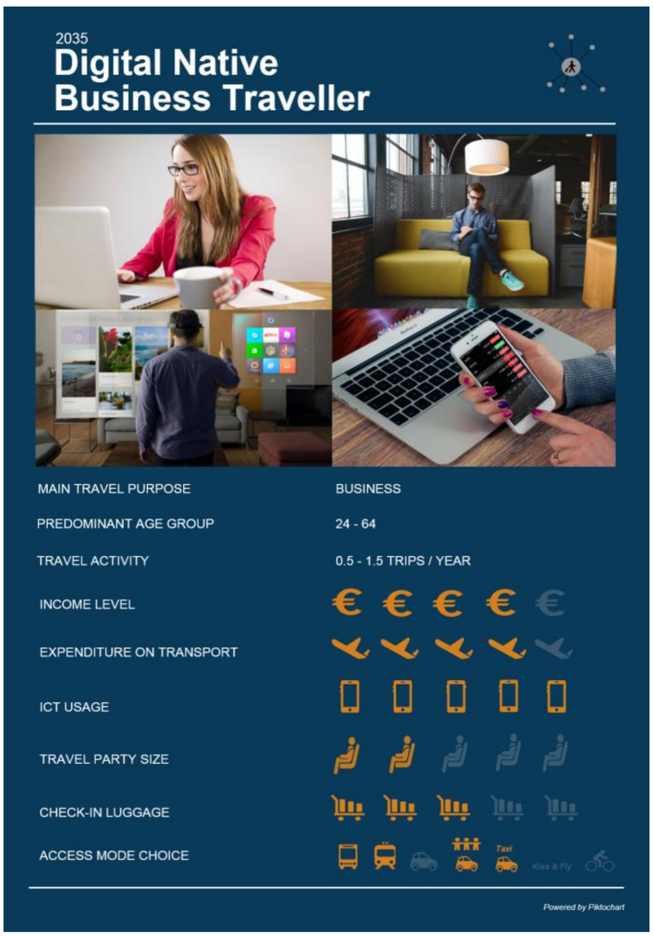

Figure 44: Overview "Digital Native Business Traveller" (own depiction)

4.3 Implications for 2050

Although the year 2050 is far away from today and predicting the future can be challenging, based on the data and information explored within this report, several implications can be derived.

Main travel purpose

The working age population (ages 15 to 64) for the EU28 countries is predicted to shrink from 66 per cent today to 57 per cent in 2050. Assuming a retirement age of around 65 years, one can say that less people will be working, which might decrease the number of business trips. Moreover, emerging technologies, such as virtual presence for meetings and conferences, could further improve and be used as a substitute for a physical journey in 2050. Following, this could lead to a decrease in business trips as well. However, better connectivity and exchange between business partners and in private life can foster the demand for physical meetings and hence also spur the demand for air travel.

Predominant age group

In 2050, almost 30 per cent of the overall European population is predicted to be 65 years or older. At the same time, there is an increasing average life expectancy across EU28 and EFTA countries. Hence, passengers will become older, live longer and increasingly comprise a large share of all air transport passengers. It might be worth thinking about grouping the *Best Agers (Next Generation)* passenger type into two different subgroups in 2050, such as one for passengers ageing 64 to 79 and another for 80+.

Income Level

Taking GDP as a proxy for income, there will be a constant income growth in almost all EU28 and EFTA countries until 2050. However, income levels will vary between countries.

Amount for transport expenditure

It is difficult to predict the share of income, i.e. amount of money, spent on transport in 2050. The share and amount depends on several factors such as the overall income level, the propensity to travel, or the substitution potential of new technologies, for example. Furthermore, new business and mobility concepts may evolve, as shortly addressed in section 2.7 on mobility aspects which alter the way people travel in the future and hence also influence the level of transport costs.

Use of technical devices and respective retrieval of Information

Usage of information and communication technologies will further increase as well as ubiquitous connectivity along the entire passenger travel process.

Travel activity (trips per capita per year)

As discussed above, the income level is predicted to grow in almost all considered countries, which might lead to an increase in discretionary income spent on holidays and air travel. Hence, throughout all profiles, the travel activity per capita per year could increase in 2050.

Travel party size

Trends indicate a higher share of single households until 2050, having more passengers travelling on their own, with a friend, or within an organized travel group at the destination. Hence, the travel party size of one to two people might increase.

Luggage requirements of passenger

New boarding concepts, stricter rules, an increase of the sharing economy or the market power of low cost carrier (LLC) could reduce the number of checked-in baggage throughout all passenger types. However, future data and forecasts for these potential developments do not exist and predictions are therefore difficult to make.

Airport access mode choice

Passenger air travel demand might be influenced by the airport access mode quality. All countries of the EU28 and EFTA country group (apart from Liechtenstein) will have an urbanisation level of at least 60 per cent in 2050 and fast and reliable accessibility to respective airports will hence also be essential to achieve the 4hD2D goal. Shared mobility and autonomous driving could further change the transport mode landscape until 2050.

Value of time

The value of travel time is influenced by different factors like income or travel purpose (see section on mobility aspects). It hence requires a detailed analysis of the development of these factors including passenger preference analysis. The increased use of information and communication technologies as well as ubiquitous connectivity along the entire passenger travel process may lead to a decrease in the value of time since the travel time can be used for other purposes.

4.4 Passenger D2D trip modelling

4.4.1 Current passenger D2D trip modelling

The allocation of passengers to flights and passenger type categorisation are important to the model, especially with regard to the output metrics (D4.2 Future supply profile). As introduced in D4.1, passenger trips are currently modelled gate-to-gate for 200 airports, uniquely with individual itineraries which include full connectivities (i.e. a proportion with connecting flights). These itineraries are to be extended to cover passenger trips door-to-gate (D2G) and gate-to-door (G2D).

In modelling the current scenario, flights that submitted flight plans for 12SEP14 to/from 200 ECAC and 50 non-ECAC airports (based on the highest ACI EUROPE passenger totals in 2014[12]), have been considered. 12SEP14 was selected as a busy traffic day, free of exceptional delays, strikes or adverse weather, however such flights may still be disrupted with respect to their published schedules, i.e. delayed, cancelled or diverted (D4.2 Section 4).

The generation of passenger itineraries deploys datasets from two time periods: individual itineraries for one day in September 2010 (used in the 'POEM' model – Cook et al. (2013); and a sample of anonymised, individual itineraries from September 2014 provided by a global distribution system (GDS) service provider. In order to calibrate the data to September 2014, aggregated passenger data from ACI EUROPE[13] and Eurostat passenger flows have been considered alongside published airline load factors (Eurostat, 2016e). Overall, passenger growth at the selected ECAC airports from 2010 to 2014 was between 13 to 16 per cent (according to available Eurostat and ACI EUROPE annual data).

For each individual passenger's itinerary, all possible options have been computed considering the available flights on 12SEP14. This computation ensured that passenger itineraries with more than one leg were able to make their connection at the intermediate airport(s), whilst respecting the minimum connecting time (MCT). These options were then preference-scored based on a set of parameters that include the characteristics of the airlines used on multi-leg itineraries (e.g. airlines being members of the same alliance, or partners within an airline group), total itinerary duration and waiting times at connecting airports (where applicable).

Having created a database of viable passenger itineraries for 12SEP14, the next task allocates passengers to the individual flights. Data preparation tasks identified non-commercial passenger flights (i.e. those not requiring passengers), assigned operator name, airline type, schedule times and seating capacity. A load factor for each of four airline types, derived from available SEP14 airline reference values, established an overall passenger target of approximately 3.8 million passengers (see Table 5).

[12] *ACI EUROPE personal communication.*
[13] *ACI EUROPE personal communication.*

Table 5: Estimated total passengers on 12SEP14 (own depiction)

Flights in scope	Seating capacity	Load factor per airline type	Estimated passengers	Overall load factor
26 000	4.5 million	Charter: 91% Full-service: 84% Low-cost carrier: 90% Regional: 75%	3.8 million	84%

Respecting the available seating capacity on each aircraft, itineraries are assigned iteratively, and probabilistically – to ensure that the final assignment reflected the variability observed in actual operations in terms of itineraries and fares. After this assignment, a capacity evaluation ensures that all flights are within their targeted load factor: if required, some itineraries are thus (stochastically) removed from flights. After this, process, unallocated, target itineraries are assigned to another flight.

This iterative process is run sequentially with the data sources. At the end of the process, flights still requiring passengers are allocated new itineraries generated based on the characteristics of existing passengers' itineraries. Finally, a passenger type ('premium' / 'standard') allocation is made. ('Premium' passengers are highest-yield passengers associated with high-end fares, who may be reaccommodated first during disturbances - see D4.2 Section 4.1) In total, there are over 3 million passengers in the modelled 'current' day, each with an assigned itinerary. The following figure shows the main processes for the generation of the itineraries.

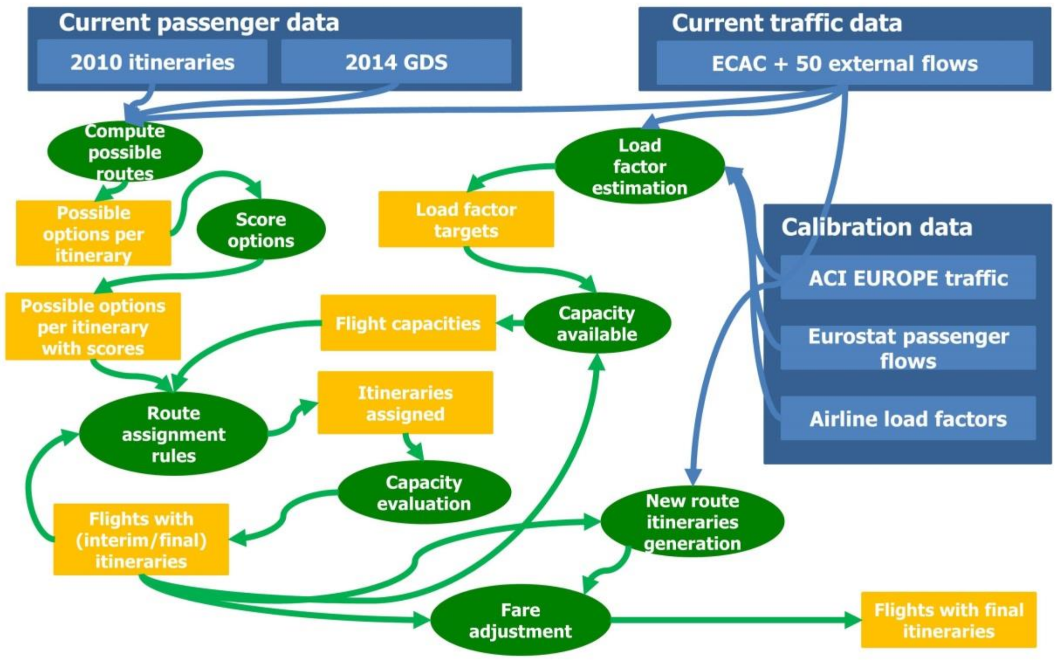

Figure 45: Modelling current passenger itineraries (own depiction)

4.4.2 Future passenger D2D trip modelling

Modelling passenger trips for the future scenarios will retain the itinerary-based approach described in the previous section, extended to cover door-to-door (D2D). The future passenger itineraries will be assigned using a combination of sample generation based on conditional probabilities, taking into account passenger profiles, and current passenger itineraries. Premium and standard passenger types will be expanded to cover six future profiles (see Table 6).

Table 6: Assignment of future passenger profiles to premium and standard passenger types (own depiction)

	Premium passenger type	Standard passenger type
Cultural Seeker	X	
Family and Holiday Traveller	X	
Single Traveller		X
Best Agers (Next Generation)		X
Environmental Traveller		X
Digital Native Business Traveller	X	

Not all the phases of the door-to-door journey will be equally affected by the distinction between passenger types. The characteristics of the passengers will, in general, play a more major role in the door-to-gate (e.g. regarding airport access mode), and, to a lesser extent the gate-to-door phases (e.g. regarding uptake of new technologies for ticketing and security clearance) than in the gate-to-gate phase. However, in the gate-to-gate phase, passengers may be differentially prioritized, subject to future business and regulatory processes, according to such factors as their uptake of new technologies (e.g. use of in-trip recovery tools) and journey travel-time priorities (e.g. some passengers being more prepared to accept late arrival times during disruption or volunteering for a later flight in cases of flight overbooking). The total number of passenger categories considered within the model might vary as a function of the travel phase, whereby some of the six profiles cited above might be collapsed into fewer categories if some are ultimately deemed to be equivalent as far as responses to model processes are concerned (e.g. rebooking during disruption).

5 SUMMARY AND NEXT STEPS

Within this deliverable, the future development of aspects driving passenger demand for mobility in general, for air transport in particular as well as influencing passenger behaviour within the predefined EU28 and EFTA countries have been discussed for 2035 and 2050. The focus was on demographical, geographical, socio-economic and behavioural aspects. Results from D3.1 and a high-level factor identification have been used as a basis as well.

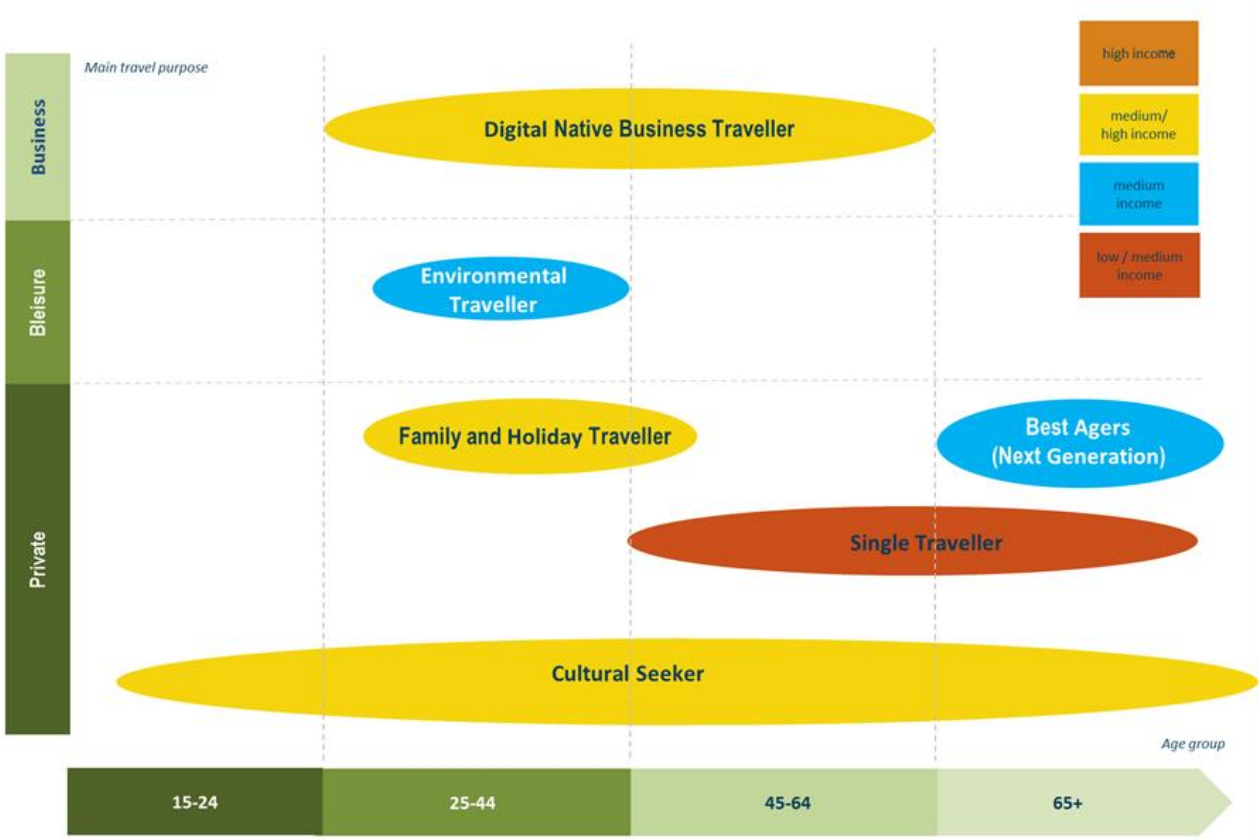

Figure 46: DATASET2050 future passenger profiles (2035) (own depiction)

A demand model was built using the simulation tool AnyLogic and a system dynamics approach, showing the high relevance of GDP growth and education as drivers on passenger demand. From 2035 to 2050, the model simulates an annual passenger traffic growth of around 3.5 per cent for the considered country set. Moreover, passenger D2D trips have been modelled.

Based on the analysis, six future demand passenger profiles for 2035 have been generated, as depicted in Figure 46, and implications for passenger types in 2050 have been discussed. Passenger profiles can be distinguished by factors like main travel purpose (private, bleisure, and business), predominant age group, income level (low, medium, high) and several other characteristics. In general, passengers are predicted to be older in 2035. Fewer passengers will travel for business purposes only and try to connect business and private trips (bleisure). Party size is decreasing, as many people will live in one-person households.

The outcomes of the current deliverable will be put in contrast with those coming from D4.2 (Future supply profile), enabling this way a complete assessment on the European door-to-door mobility in the future. Specifically, the deliverable results will be used in D5.1 (Mobility assessment), D5.2 (Assessment execution) and D5.3 (Novel concept foundations for European mobility).

6 APPENDIX

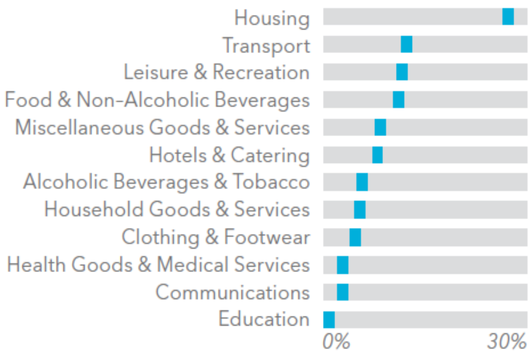

Figure 47: Norwegian Consumer Expenditure of single person households; per cent of total spending in 2013 (data: Euromonitor International, 2014)

Passenger_Air_Travel_Demand $\xrightarrow{+}$ GDP_Growth $\xrightarrow{+}$ Income $\xrightarrow{+}$ Education_Level $\xrightarrow{+}$ Women_in_tertiary_Enrolments $\xrightarrow{+}$ working_Women $\xrightarrow{+}$ Travel_for_business_Purposes $\xrightarrow{+}$ Passenger_Air_Travel_Demand

Passenger_Air_Travel_Demand $\xrightarrow{+}$ GDP_Growth $\xrightarrow{+}$ Income $\xrightarrow{+}$ Education_Level $\xrightarrow{+}$ Passenger_Air_Travel_Demand

Passenger_Air_Travel_Demand $\xrightarrow{+}$ GDP_Growth $\xrightarrow{+}$ Income $\xrightarrow{+}$ Education_Level $\xrightarrow{+}$ Women_in_tertiary_Enrolments $\xrightarrow{+}$ working_Women $\xrightarrow{+}$ Childbirth_Age $\xrightarrow{-}$ Children_per_Household $\xrightarrow{-}$ Passenger_Air_Travel_Demand

Passenger_Air_Travel_Demand $\xrightarrow{+}$ GDP_Growth $\xrightarrow{+}$ Income $\xrightarrow{+}$ Travel_for_private_Purposes $\xrightarrow{+}$ Passenger_Air_Travel_Demand

Children_per_Household $\xrightarrow{-}$ Number_single_Person_Households $\xrightarrow{-}$ Children_per_Household

Income $\xrightarrow{+}$ GDP_Growth $\xrightarrow{+}$ Income

Income $\xrightarrow{+}$ Education_Level $\xrightarrow{+}$ Income

Births $\xrightarrow{+}$ Population_Growth $\xrightarrow{+}$ Births

Deaths $\xrightarrow{-}$ Population_Growth $\xrightarrow{+}$ Births

Emerging_Technology $\xrightarrow{+}$ Data_Security_Concerns $\xrightarrow{-}$ Emerging_Technology

alternative_Transport_Modes $\xrightarrow{+}$ changing_Mobility_Patterns $\xrightarrow{+}$ alternative_Transport_Modes

Figure 48: Feedback loops (own depiction)

Table 7: Data input passenger demand model real GDP growth rate (data: various)

Year	Real GDP growth rate - percentage change on previous year (EU28/ EU[14]) (in per cent)	Region	Source of data
2012	-0.5	EU28	Eurostat statistics
2013	0.2	EU28	Eurostat statistics
2014	1.6	EU28	Eurostat statistics
2015	2.2	EU28	Eurostat statistics
2016	1.9	EU28	European Commission forecast
2017	2	EU28	European Commission forecast
2018	2.1	EU	PWC analysis
2019	2.1	EU	PWC analysis
2020	2.1	EU	PWC analysis
2021 - 2030	1.9	EU	PWC analysis
2031 - 2050	2	EU	PWC analysis

Table 8: Data input passenger demand model education (data: Wittgenstein Centre Data Explorer, 2016)

Year	Share population with tertiary education of total population for EU28 and EFTA countries[15] (in per cent)	Growth rate (in per cent)	Source of data
2012	17.48	0.30	Wittgenstein Centre Data Explorer
2013	17.78	0.30	Wittgenstein Centre Data Explorer
2014	18.07	0.30	Wittgenstein Centre Data Explorer
2015	18.37	0.30	Wittgenstein Centre Data Explorer
2016	18.64	0.28	Wittgenstein Centre Data Explorer
2017	18.92	0.27	Wittgenstein Centre Data Explorer
2018	19.19	0.27	Wittgenstein Centre Data Explorer
2019	19.47	0.27	Wittgenstein Centre Data Explorer
2020	19.74	0.27	Wittgenstein Centre Data Explorer
2021	20.02	0.28	Wittgenstein Centre Data Explorer

[14] *EU = not further defined which countries are included*

[15] *data for Cyprus and Liechtenstein missing*

Year	Share population with tertiary education of total population for EU28 and EFTA countries[15] (in per cent)	Growth rate (in per cent)	Source of data
2022	20.30	0.28	Wittgenstein Centre Data Explorer
2023	20.58	0.28	Wittgenstein Centre Data Explorer
2024	20.86	0.28	Wittgenstein Centre Data Explorer
2025	21.13	0.28	Wittgenstein Centre Data Explorer
2026	21.49	0.35	Wittgenstein Centre Data Explorer
2027	21.84	0.35	Wittgenstein Centre Data Explorer
2028	22.20	0.35	Wittgenstein Centre Data Explorer
2029	22.55	0.35	Wittgenstein Centre Data Explorer
2030	22.90	0.35	Wittgenstein Centre Data Explorer
2031	23.22	0.31	Wittgenstein Centre Data Explorer
2032	23.53	0.31	Wittgenstein Centre Data Explorer
2033	23.85	0.31	Wittgenstein Centre Data Explorer
2034	24.16	0.31	Wittgenstein Centre Data Explorer
2035	24.47	0.31	Wittgenstein Centre Data Explorer
2036	24.81	0.34	Wittgenstein Centre Data Explorer
2037	25.15	0.34	Wittgenstein Centre Data Explorer
2038	25.49	0.34	Wittgenstein Centre Data Explorer
2039	25.82	0.34	Wittgenstein Centre Data Explorer
2040	26.16	0.34	Wittgenstein Centre Data Explorer
2041	26.49	0.33	Wittgenstein Centre Data Explorer
2042	26.82	0.33	Wittgenstein Centre Data Explorer
2043	27.14	0.33	Wittgenstein Centre Data Explorer
2044	27.47	0.33	Wittgenstein Centre Data Explorer
2045	27.80	0.33	Wittgenstein Centre Data Explorer
2046	28.13	0.33	Wittgenstein Centre Data Explorer
2047	28.45	0.33	Wittgenstein Centre Data Explorer
2048	28.78	0.33	Wittgenstein Centre Data Explorer
2049	29.11	0.33	Wittgenstein Centre Data Explorer
2050	29.44	0.33	Wittgenstein Centre Data Explorer

Table 9: Short description of future passenger profiles (2035) (own depiction)

	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	Business
Predominant age group	15 – 65	30 – 50 + children below 15	44+	65+	30 – 44	24 – 64
Income level	Medium / high	Medium / high	Low / medium	Medium	Medium	Medium / high
Amount for transport expenditure	Medium / low	Medium	Low	Medium	Low	Medium / high
Use of technical devices and respective retrieval of information	High frequency	Medium frequency	Medium frequency	Medium frequency	Low / medium frequency	High frequency
Travel activity (trips per capita per year)	0.5 – 1.5	0.5 – 1.5	0.25 – 0.5	0.5	0.5 (as few as possible)	0.5 – 1.5
Travel party size (in number of people)	1 - 2	2 - 3	1	1 - 2	1 - 2	1 - 2
Luggage requirements of passenger	Hand luggage only (short trips) Check-in luggage	Check-in luggage	Hand luggage only (short trips) Check-in luggage	Check-in luggage	Hand luggage only (short trips) Check-in luggage (if necessary)	Hand luggage only (short trips) Check-in luggage
Access mode choice	Public transport Taxi Car Sharing	Public transport Private car (park and travel)	Public transport Kiss & fly	Private car (park and travel) Kiss & fly	Public transport Car Sharing Cycling (if possible)	Public transport Taxi Car Sharing

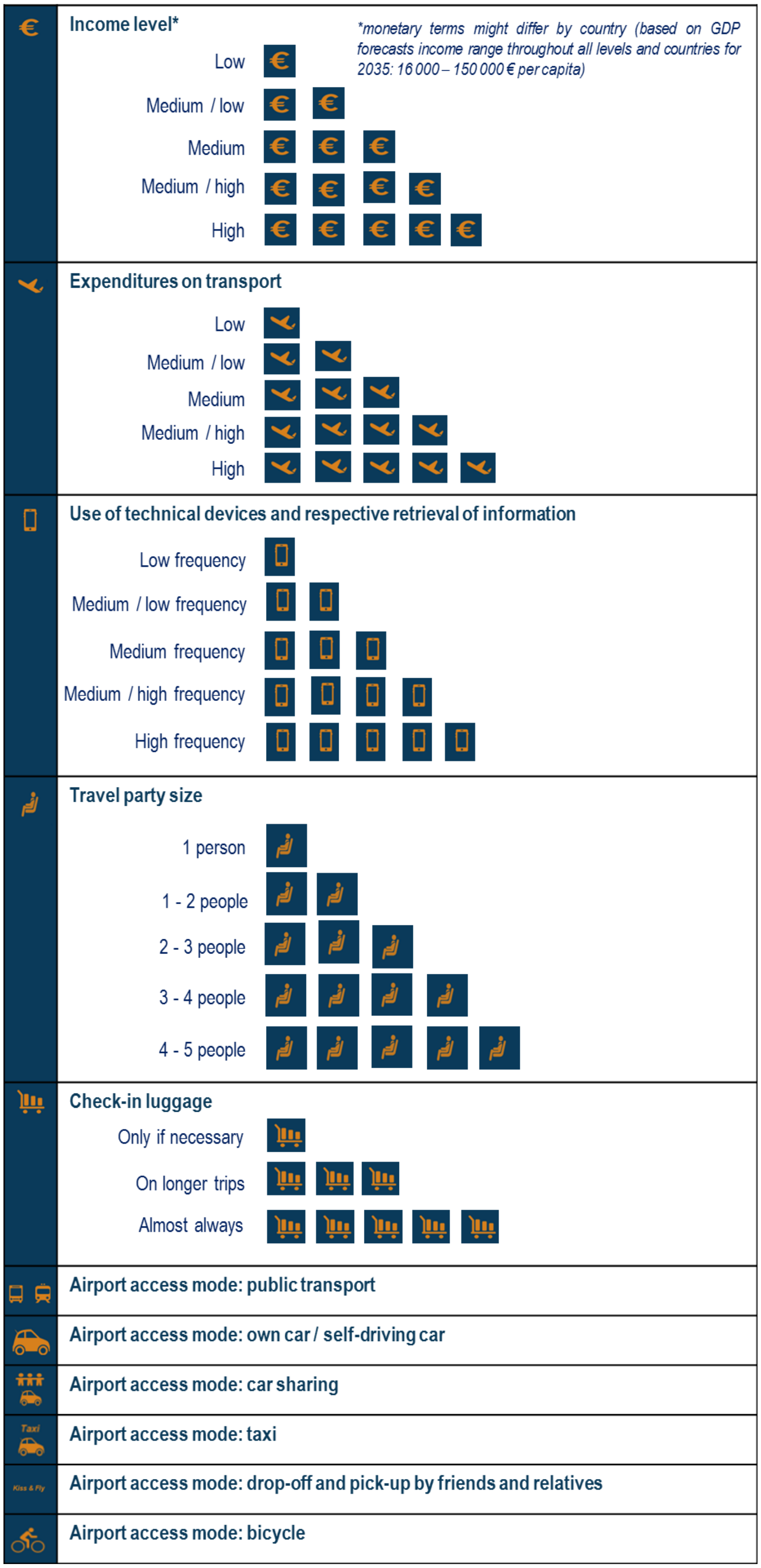

Figure 49: Additional information passenger profiles (own depiction)

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