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D5.3

ASSESSING PASSENGER REQUIREMENTS ALONG THE D2D AIR TRAVEL CHAIN*

(*Previous title: Novel concept foundations for European mobility)

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DATASET2050

DATA DRIVEN APPROACH FOR A SEAMLESS

EFFICIENT TRAVELLING IN 2050

Coordination and Support Action funded by the European Commission H2020, Mobility for Growth

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Abstract

The Flightpath 2050 goal of enabling 90% of European passengers to complete their door-to-door journey within four hours is a very challenging one. A major objective of the DATASET2050 project is to deliver insight into both current and future processes relating to the European transport system with a view to enabling this goal to be attained.

In this regard, this final deliverable, D5.3 "Assessing Passenger Requirements along the Door-to-Door (D2D) Air Travel Chain" focuses on the future demand side as well as the current and future supply side of the European (air) transport market. In line with the DATASET2050 project, an intermodal, user-centric and data driven approach is taken.

Based on the needs and requirements of future travellers, passenger-centric assessment parameters and respective key performance indicators are developed. Having applied these to evaluate the performance of current as well as future European mobility solutions, several gaps and bottlenecks in need of improvement in order to meet future mobility goals are revealed and discussed.

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1. Introduction

1.1 DATASET2050 Introduction

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

- The objective of DATASET2050 is the provision **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. The main focus is to analyse how the **European transport supply profile** (capacity, connections, business models, regulations, intermodality, processes, infrastructure) could adapt to the **evolution of the demand profile** (customers, demographics, passenger expectations, requirements);
- DATASET2050 addresses the **main transport mobility goal** stated in the Flightpath 2050: 90% of travellers within Europe are able to complete their journey, door-to-door within four hours. Through the application of statistical analyses, multi-modal mobility modelling and predictive analytics, DATASET2050 will compute the **current status** of air transport mobility across Europe;
- The analyses will enable the identification of **transport bottlenecks** in the current scenario and across different future scenarios. These findings will serve as a basis for the development of **intermodal transport concepts**; identifying possible solutions for current and predicted shortcomings. The insights gained will highlight **research needs and requirements towards the four-hour door-to-door goal** formulated by ACARE. Due to the multi-dimensionality of the problem, DATASET2050 will use visualisation techniques, to ease understanding of the results;
- DATASET2050 partners are supported by an Advisory Board, made up of key **European transport stakeholders**;
- The **dissemination and communication** plans ensure efficient circulation of results among key European transport policy makers and stakeholders. The plans also incorporate their valuable input and perspectives, obtained during the project workshops.

1.2 WP5 and Deliverable 5.3 context

The aim of the section is to set and clarify the deliverable context, in order for it to be as self-contained as possible:

- WP2, at the beginning of the project, listed the data requirements and data acquisition (**D2.1**) and provided details on the data-driven mobility model (**D2.2**)
- WP3 was then devoted to the mobility demand profile (customers, demographics, passenger profiles, etc.), with a deliverable on current status **D3.1** and one on the future scenarios/future passenger profiles, both in 2035 and 2050 (**D3.2**).
- In a symmetric approach, WP4 tackled the current and future European transport supply side (airports, means of transport available, connection times, metrics) for passenger journeys. WP4 is also divided

into **D4.1** on the current supply status and **D4.2** that considers the future supply profile (in 2035 and 2050).

The aim of WP5 is to merge, consolidate, and document the main project outcomes at all levels, now that all the previous steps are accomplished:

- On one hand describing and documenting the innovative mobility assessment metrics / KPAs and KPI developed **(D5.1**),
- On the other, the DATASET2050 model provides quantitative information regarding the transport processes. In brief, this meant presenting the results of the computation/simulation of the door-to-door metrics in both current and future scenarios. (**D5.2**)

The novel concept foundations for EU mobility (the present D5.3) is the very last technical project deliverable

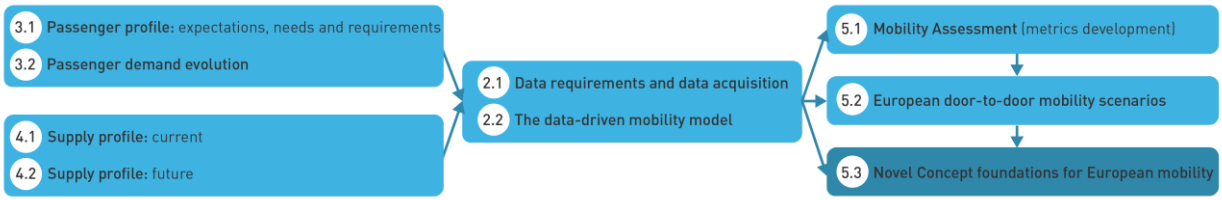


Figure 1: Relationship between DATASET2050 deliverables

1.3 Deliverable structure and content

Deliverable 5.3 focuses on passenger-centric assessment parameters and related key performance indicators (KPIs), the collection and clustering of existing and future inter-modal mobility solutions as well as their assessment according of the KPIs introduced earlier. Following this, gaps and bottlenecks with regard to passengers' (future) needs, requirements and the Flightpath 2050 4-hour door-to-door (4HD2D) goal will be identified and discussed, including the proposal of new approaches. The report is composed of six main sections, following this introduction.

- Section 2 describes the derivation of passenger-centric assessment parameters and related KPIs, based on current and future demand profiles (D3.1 and D3.2) as well as future passenger needs and requirements towards the European transport system, derived from these profiles.
- Section 3 describes the collection process of existing and novel intermodal mobility solutions (database), including cutting-edge mobility products such as transport on demand or piloted flying mobility, as well as the structuring of these results. The definition of mobility clusters and mobility concept classes will also be presented.
- Section 4 assesses the aforementioned mobility clusters according to passenger-centric KPIs, developed in Section 2. Evaluation results are presented and discussed in detail.
- Section 5 identifies gaps and bottlenecks within the current and future European transport system, based on passenger requirements and needs. Moreover, the overall project results of DATASET2050 (derived from all work packages) are compared to the ACARE SRIA goals.
- Section 6 concludes with an overall summary.

2. Passenger-centric assessment parameters and key performance indicators

2.1 Introduction and Definition of KPIs

The words "performance indicator" (PI) are defined by the Collins English Dictionary (2017) as: "*a quantitative or qualitative measurement, or any other criterion, by which the performance, efficiency, achievement, etc. of a person or organisation can be assessed, often by comparison with an agreed standard or target*". In regards to the overall goals of the DATASET2050 project and the objective of this deliverable, "key performance indicator" (KPIs) should hence depict, monitor and measure the development, strengths and weaknesses of transport projects, innovative ideas, or (existing and future) (inter-modal) mobility concept or solution. They should be formulated clearly, understandable, and measureable in respect to meeting future aviation and air transport mobility goals in Europe, such as the Flightpath 2050 4HD2D goal.

Passenger KPIs have already been developed within other studies, such as by Urban et al. (2017). Urban et al. developed high-level passenger KPIs and evaluated the current performance status of existing intermodal concepts in regards to the Flightpath 2050 goal of seamless travel. However, the study lacks a focus on future mobility solutions. The CSA Mobility4EU (2016) does also develop specific user needs (similar to KPIs), which are derived from current and future societal and economic trends shaping the transport world in 2030. In this context, users not only encompass the demand side, but also the supply side as well as requirements from political institutions. In a second step, these user needs are taken further to evaluate novel mobility solutions for all modes (air, rail, waterborne, road, urban mobility and freight) (Mobility4EU, 2016).

In the following, twelve passenger assessment parameters, that are extracted from WP3 (D3.1 & D3.2), are proposed (Figure 2). They cover the demand side only and focus on overall critical customer-centric components, derived from possible future needs and requirements of European passengers towards the transport system. In line with the data driven approach of the DATASET2050 project, all parameters are backed up with data, studies or other available sources. To measure these assessment parameters, 41 KPIs are formulated and assigned to overall assessment parameters. They will serve as inputs for the assessment of mobility clusters at a later stage in this report. The next section will elaborate on each assessment parameter in more detail as well as introducing respective KPIs.

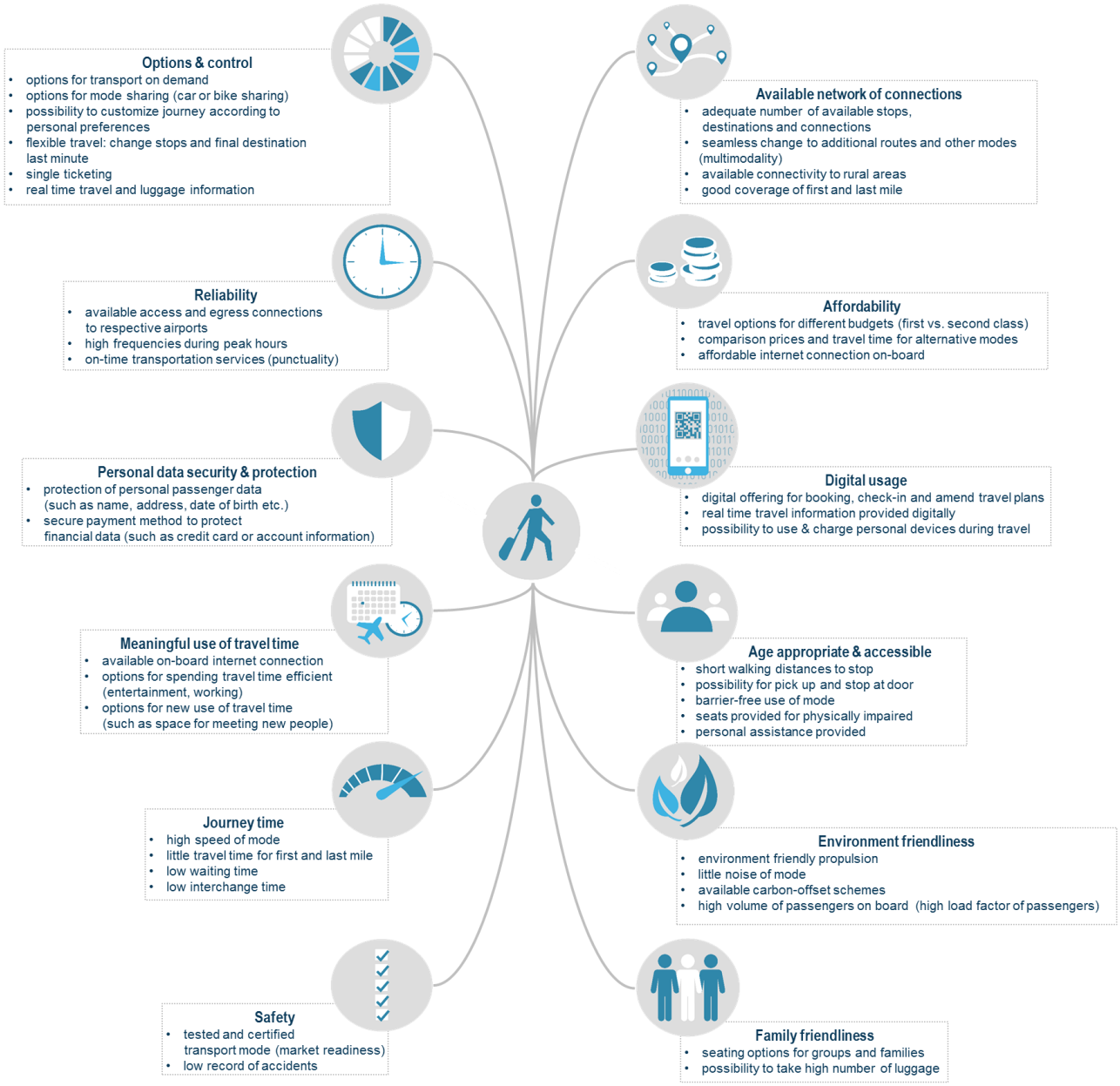


Figure 2: Twelve passenger-centric assessment parameters have been identified

2.2 Assessment parameters and KPIs

2.2.1 Age appropriate & accessible

The age structure within the EU28 and EFTA countries is going to change until 2050 towards an aging population. Around 30% of the people living in this considered country set will be 65 years or older (Eurostat, 2016a). In other words, almost 1/3 of the European population will be retired or on the brink of retirement. At the same time, the average life expectancy is going to increase. On average, women will become 88 years and men 83 years in 2050 (Eurostat, 2016b). The changing age structure has already been discussed in detail in deliverables D3.1 and D3.2.

An ageing population will result in a higher share of elderly travellers, who have certain requirements and needs towards travel and who differ in travel behaviour than younger counterparts (Alsnih & Hensher, 2003; Möller et al., 2007). For instance in some cases, elderly passengers might not able to drive their own vehicle anymore and are more dependent on public transport modes. In regards to the Flightpath 2050 4HD2D goal, elderly travellers are more likely to use buses and railway as access and egress options. Moreover, public transport provides senior citizens with a sense of freedom, independence and dignity. Creating the adequate transport environment for elderly passengers is required and future modes, concepts and mobility solutions should be age appropriate and provide accessibility for older passengers. This will especially meet the needs of the current and future passenger profile of the "Best Agers" (current and future generation) (see D3.1 and D3.2).

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) short walking distances to stop

2) possibility for pick up and stop at door

3) barrier-free use of mode

4) seats provided for physically impaired

5) personal assistance provided

2.2.2 Affordability

The Gross Domestic Product (GDP) is one indicator for the overall economic performance of a country and one of the main drivers on passengers' air transport demand, as already explored within many studies such as by Profillidis and Botzoris (2015). GDP per capita is often used as a proxy for the income level per person, which influences the demand for air travel directly and indirectly (Kluge & Paul, 2017).

Generally, the GDP per capita for the EU28 and EFTA countries will grow constantly until 2050, however, will also vary strongly on a country level. Some nations, such as Croatia or Romania, are already countries with currently low GDP per capita figures and face only a small GDP growth until 2050 (ifs, 2014). At the same time, air travel (especially the emerging LCCs) in eastern European countries are important to keep migrants and their families mobile, despite their low income levels (Kuljanin & Kalić, 2015). As income will differ across Europe, travel options along the travel chain (D2D) for different budgets should be provided to make mobility affordable and accessible to everyone. This will also meet future needs of the "Single Travellers", who will possess a low to medium income level as well as the "Cultural Seekers" and "Environmental Travellers", both likely to spend a low to medium amount on transport.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) travel options for different budgets (first vs. second class)

2) comparison prices and travel time for alternative modes

3) affordable internet connection on-board

2.2.3 Available network of connections

Besides demographic and economic developments as seen in the previous two parameters, the degree of urbanisation will increase throughout the EU28 and EFTA countries. By 2035 and 2050, all countries apart from Liechtenstein will have an urbanisation level of at least 50 and 60 per cent respectively (UN, 2015).

Hence, a high accumulation of passengers will live in urban areas alone, making these highly demanded places of departure and possible destinations. As a high share of the population depends on it, "Available network of connections" should be considered when assessing current and novel mobility solutions. Fast, reliable accessibility to and from respective airports has to be ensured both from within these urban agglomerations and also from rural areas, since lots of trips have a private motivation and holiday destinations can also be located in the countryside. Moreover, seamless changes to other modes should also be considered with regards to the 4HD2D goal.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) adequate number of available stops, destinations and connections

2) seamless change to additional routes and other modes (multimodality)

3) available connectivity to rural areas

4) good coverage of first and last mile

2.2.4 Digital usage

The use of information and communications technology (ICT) within passenger groups is already present and travellers of the future wish to complete more duties around their journey using own devices, such as for booking, check-in or amend travel plans (Future Foundation, 2015). At the same time, this 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).

In fact, passengers could benefit from more digital usage during travel in order to experience a hassle-free journey, save (travel) time, improve the overall travel experience, but also using travel time more efficiently, such as for getting work done (see section on "Meaningful use of travel time"). Moreover, “Digital usage” before departure and while travelling is essential to meet future passenger needs, such as from the "Cultural Seeker" and the "Digital Native Business Traveller", who will both use technical devices and respective retrieval of information with a high frequency.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) digital offering for booking, check-in and amend travel plans

2) real time travel information provided digitally

3) possibility to use and charge personal devices during travel

2.2.5 Environment friendliness

Recent studies show initial evidence of the emerging willingness of passengers to adapt their travel behaviour according to pro-environmental mindsets and values (Cohen & Higham, 2011; Gössling et al., 2009). This willingness, for instance, could translate into the increasing usage (shown by a willingness to pay) of carbon offsetting schemes in order to compensate their own air journey.

For this reason “Environment friendliness” should be included as an assessment parameter as well, also matching the preferences, needs and requirements of the future profile of the “Environmental Traveller”. However, it needs to be mentioned that only a small amount of future passengers might want to travel in an eco-friendly way. More information on the environmental awareness of current and future passengers can be found in the deliverable D3.1 and D3.2. The "Environment friendliness" can be measured with the type of propulsion or noise level of modes, the number of offered carbon-offset schemes and the load factor of passengers per journey.

Hence, the following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) environment friendly propulsion

2) little noise of mode

3) available carbon-offset schemes

4) high volume of passengers on board (high load factor of passengers)

2.2.5 Family friendliness

Although the number of children per household is going to decrease and the number of single person households is going in increase, there are still on average 0.5 children per house predicted for 2020 for both Eastern and Western Europe (Euromonitor International, 2013; Euromonitor International, 2014).

Families will make up a fair share of air passengers, such as seen by the example of the future demand profile of the "Family and Holiday Traveller". Their travel preferences and needs differ compared to other ones. For instance, passengers travelling with children are more likely to arrive early at the airport to have more dwell time, prefer to sit together as a group or have more luggage than other traveller profiles. Hence, mobility solutions should not only be age appropriate and easily accessible for elderly passengers but also family-friendly for passengers travelling with children and family.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) seating options for groups and families

2) possibility to take high number of luggage

2.2.7 Journey time

The travel time of a journey plays an essential role when analysing the current and future mobility landscape in regards to the 4HD2D goal. The value of travel time (VoT) can be impacted due to changes of demand drivers. Studies have shown that the VoT increases with the age of passengers (depending on other parameters as well, such as pre-retirement wage rate) and with an increase in income (Alsnih & Hensher, 2003; Möller et al., 2007; Sun & Ng, 2009; Wardman et al., 2012).

The EU28 and EFTA countries are facing both developments in the future, an ageing population as well as an increase in the income levels across some countries (Eurostat, 2016a; ifs, 2004). Hence, the "Journey time" is an additional assessment parameter, not just important for future passengers but also for reaching the 4HD2D goal. "Journey time" can be reduced, for instance, during mode change or when modes run with a high frequency.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) high speed of mode

2) short travel time for first and last mile

3) low waiting time

4) low interchange time

2.2.8 Meaningful use of travel time

Time gets a more and more scarce resource and, nowadays and in the near future, travel time can be used much more efficiently with the increased usage of ICT among passengers. For instance, the "Digital Native Business Traveller" is very connected and in constant digital exchange with private life, friends and family. Moreover, he or she can use travel time to conduct work-related tasks (for more information see D3.2). Besides, 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, indicating that the useful use of travel time gets increasingly important for passengers (Fraunhofer IAO & Horváth & Partners, 2016).

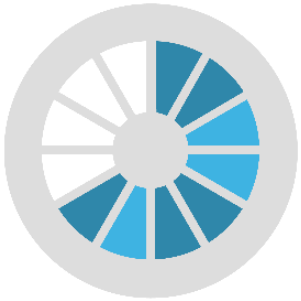
Hence, the "Meaningful use of travel time" can become an important passenger need and the following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) available on-board internet connection

2) options for spending travel time efficient (such as entertainment or working)

3) options for new use of travel time (such as space for meeting new people)

2.2.9 Options & control



Passengers are going to become increasingly diverse, as seen within the future demand profiles of the DATASET2050 project. The groups vary in their predominant age, income level, travel activity and main travel purpose, budget for transport, ICT usage, luggage for check-in but also travel party size or access and egress mode choices (see D3.2 for more details). According to these profiles, travel preferences might differ as well. For instance, the "Environmental Traveller" might want to go on a journey as eco-friendly as possible, while the "Cultural Seeker" is more concerned with broadening their personal horizon when travelling, budget options for transport and a high use of ICT before and during a journey.

Moreover, these are only high-level user groups and every passenger has own wishes and needs. Journeys should be customisable according to individual travel types, needs, requirements and travel preferences, while still providing access to real time travel information of the own journey ("Options & control"). Some of these passenger requirements are already covered by other assessment parameters: "Affordability" already addresses the offering of travel options for different budget and "Environment friendliness" does assess the option to travel eco-friendly. "Options & control", however, refers to the combination of all requirements within one mobility solution or concept and providing passengers with the necessary (real time) travel information.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) **options for transport on demand**
2) **options for mode sharing (car or bike sharing)**
3) **possibility to customise journey according to personal preferences**
4) **flexible travel: change stops and final destination last minute**
5) **single ticketing**
6) **real time travel and luggage Information**

2.2.10 Personal data security & protection

The “Digital usage” before departure and while travelling is essential to meet future passenger need. At the same time, concerns about the abuse of personal data, such as name, address or financial information, among all different age groups is already present today (ESPAS, 2015). However, many of such personal data is digitally generated before and during a flight - such as credit card information, name, home address or date of birth - often by the passenger themselves. Hence, there is a strong need for a robust data security system and data privacy regulation by the government but also by mobility providers, digital platforms and other mobility solutions. “Personal data security & protection” should be a top priority and is included as additional an assessment parameter.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) protection of personal passenger data (such as name, address, date of birth etc.)

2) secure payment method to protect financial data (such as credit card or account information)

2.2.11 Reliability

The "Reliability" of the current and future mobility landscape is crucial for passengers and for reaching the 4HD2D goal. Besides the "Best Agers" (Next Generation), all future demand profiles are likely to travel with public transport. Reliable transport as access and egress modes has to be ensured, as passengers do not want to be late at the airport, miss their flights or be late at their final destinations. Moreover, on-time transport is essential when changing modes to create a seamless travel experience.

Next to punctuality, the schedule and coverage to and from airports can provide insights concerning the "Reliability" of a mobility solution and the following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) available access and egress connections to respective airports

2) high frequencies during peak hours

3) on-time transportation services (punctuality)

2.2.12 Safety

Perceived safety is already important for today's travellers, contributing to the overall customer satisfaction, which is on the other side linked positively to customer loyalty (Gilbert & Wong, 2003; Ringle et al., 2011). At the same time, new mobility concepts are emerging, which may raise new safety concerns among passengers. For instance, self-driving modes will not have a pilot anymore and hence lacking a human control factor during a journey. One example can be seen by the Airbus project Vahana (Airbus Vahana, 2017). Hence, "Safety" is an essential factor when evaluating the future mobility landscape.

The following KPIs can be helpful in assessing whether a mobility cluster fulfils this parameter:

1) tested and certified transport mode (market readiness)

2) low record of accidents

3. Repository and analysis of mobility solutions

3.1 Database

The database that has been created in order to collect mobility solutions and structure them into various mobility concepts contains a total of **86 companies or projects** and can be found in Appendix I.

In order to document the different mobility solutions and group these into different clusters, each of the 86 projects has been analysed with regard to:

1. Company that provides the project
2. Description of the project
3. Name of the project (in case of small mobility start-ups this is often equivalent to the name of the company providing the project)
4. Number of different modes of transport that are combined with the offered mobility concept
5. Different means of transport that are used within the mobility solution
6. The degree of market penetration:
    a. Visionary (i.e. not yet realised)
    b. National (implemented only on a national level)
    c. International (already established on the international market)
7. Time of implementation (or estimated implementation for visionary concepts.)

Based on these characteristics each mobility solutions is assigned (1) to a high-level cluster which characterises a particular form of mobility and (2) to a specific mobility concept class, which describes the means of transport used or the form of vehicle ownership. The approach as well as the description of the clusters and concept classed is outlined in more detail in the following section.

3.2 Definition of mobility clusters and concept classes

Mobility clusters and mobility concepts have been decoupled to allow a better analysis of the various mobility solutions. Each mobility solution in the database (see Appendix I. Overview Mobility Cluster) is assigned to one specific concept class and to one particular mobility cluster. Structuring the solutions according to cluster and concept class enables them to be compared in a better way with regard to the previously defined passenger requirements.

- A **mobility concept class** is characterised by either a particular means of transport (e.g. car, bus, personal air vehicle, rail), or the type of sharing between users and providers (e.g. peer-to-peer, on-demand services). Each mobility solution is assigned to one of the fourteen concept classes.
- A **mobility cluster** is a high-level aggregation of different mobility solutions and their associated mobility concept class. Each of the eight clusters describes a particular form of mobility.

In a first step, by following a bottom-up approach, each mobility solution is assigned to a specific mobility concept class. Uber, for example, belongs to the "Ridesharing on demand" concept class which is characterised by a privately owned vehicle, operated by the owner of the vehicle. The user orders a ride from A to B via an app and the next available Uber car picks up the user. In addition, Uber belongs to the "On Demand Mobility" cluster, which implies that a mobility solution can be ordered by the user at any time, thus meeting just-in time demand as well as long-term planning (see Figure 3).

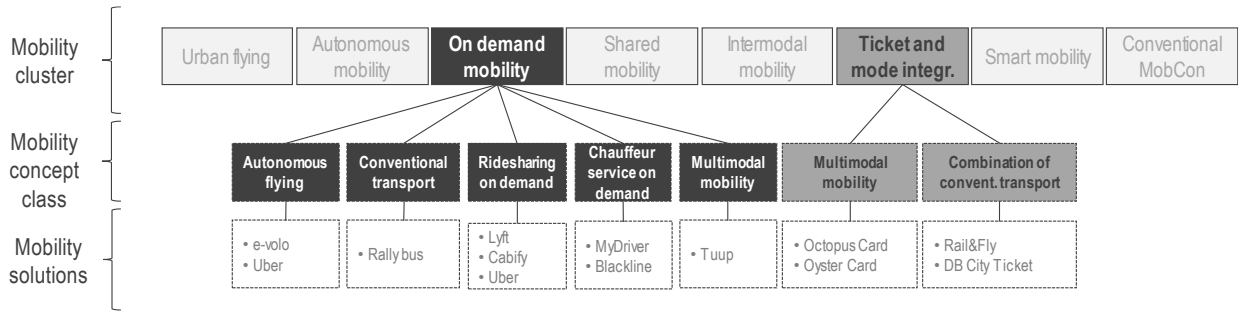


Figure 3: Approach to aggregating mobility solutions within concept classes and clusters

The differentiation between clusters and concept classes is introduced because passenger requirements can thus be assessed on an aggregated cluster level and subsequently be transferred to the concept class level. For example, if the "On Demand Mobility" cluster performs well with respect to needs imposed by passengers, the corresponding concept classes such as "Multimodal mobility", Autonomous mobility" or "Ridesharing on demand" (Figure 3) can be taken as a basis for further enhancing the European transport system. Furthermore, the incorporation of concept classes shows which means of transport dominate the transport landscape. Table 1 and Table 2 describe each cluster and concept class, respectively, in more detail.

Table 1: Overview of clusters[1]

No.	Cluster name	Icon	Description	Example mobility solutions
1	**Piloted Flying Mobility**		– Flying vehicle as main transport mode – No autonomous flight – Potential deployment in urban regions	– Joby Aviation – voom – Terrafugia – zee aero
2	**Autonomous Mobility**		– Mobility solutions operating autonomously – Includes all possible transport modes	– Volocopter – Lilium – Hyperloop One
3	**On Demand Mobility**		– Adapted to individual transport demand, no fixed schedules – Transport services are ordered via mobile platforms – Journey can be monitored digitally and exchange between provider and user possible – Vehicle is operated by third person	– Rally Bus – Lyft – Tuup – Allygator – Uber – E-volo
4	**Shared Mobility**		– Vehicle not owned by transport users – Vehicle is rented / shared and operated by individual requiring transport service	– car2go – SnappCar – Deutsche Bahn – SocialCar – BlaBlaCar
5	**Intermodal Mobility**		– Mobility solutions as feeder services – Connecting different transport modes and locations – Door-to-door mobility solutions	– busandfly – Lufthansa – AirportLiner – Mozio
6	**Integrated Mobility**		– Integrated ticketing across modes – Shared liabilities and responsibilities	– Octopus Card – Oyster Card – Clipper – mobilitymix
7	**Smart Mobility**		– Comparison of mobility solutions for specific / individual transport demand – User interface via various mobile devices / online platforms	– CarTrawler – Free2Move – 9292 – Google
8	**Conventional Mobility**		– Conventional transport modes – Fixed schedules, no on-demand services	– Flixbus – Amtrak – Thalys – Network Rail

[1] *Sources for icons*

- *https://www.onlinewebfonts.com/icon/148122*
- *https://thenounproject.com/term/self-driving-car/683448/*
- *https://www.shutterstock.com/de/image-vector/phone-icons-on-white-background-vector-128906801?irgwc=1&utm_medium=Affiliate&utm_campaign=Graphic%20resources%20SL&utm_source=39422&utm_term=1241230769.1511261367*
- *http://calculator.sharedusemobilitycenter.org/#!/*
- *https://thenounproject.com/term/puzzle/1201/*
- *https://www.flaticon.com/free-icon/ticket_110187#term=entrance&page=1&position=10*
- *http://www.thinkstockphotos.de/image/stock-illustration-wifi-symbol-icon-set/489930074*
- *https://www.flaticon.com/free-icon/underground_66273#term=train&page=1&position=*

Table 2: Overview of concepts

No.	Concept class name	Description	Exemplary mobility solutions
1	**Autonomous driving**	– Means of transport drives autonomously, no interaction with driver under all conditions, equal to SAE Level 5	Waymo (formerly GoogleCar)
2	**Autonomous flying**	– Means of transport flies autonomously, no interaction with driver under all conditions, equal to SAE Level 5	Volocopter
3	**Piloted air services**	– Means of transport flies, manual piloting required	Joby Aviation
4	**Carsharing on demand**	– Cars are part of a pool owned by a company and are constantly shared between users.	Car2Go
5	**Chauffeur service on demand**	– Driver acts as a chauffeur, cars are owned by a company.	Mozio
6	**Combined conventional transport**	– Mobility concepts that combine existing, conventional means of transport.	Rail & Fly
7	**Single conventional transport**	– Mobility concepts that use sole, existing transport means.	Flixbus
8	**Flying car**	– Vehicle is operated and controlled manually by the driver/pilot. Can both drive and fly.	Terrafugia
9	**Multimodal mobility**	– Concepts always combine various forms of mobility, either via only displaying the different options for going from A to B, or via providing various transport options for going from A to B. – Important: to determine the number of different modes used by multimodal mobility concepts, the number of main modes connected by the concept is used!	Oyster Card (but also e.g. GoogleMaps)
10	**Peer to peer carsharing**	– Car that is used for carsharing is owned by a private person who is paid for leasing his car to others	SocialCar
11	**Ridesharing on demand**	– Means of transport is privately owned, driver typically drives to earn money on top of a normal job. User requests a ride from A to B using an app, nearest available car picks them up.	Uber
12	**Scooter on demand**	– Electric scooters can be rented on demand to get from A to B.	Yugo
13	**Next generation train**	– Usage and implementation of new technology in trains.	Hyperloop
14	**Bikes on demand**	– Bikes can be rented on demand to get from A to B.	Velib

The different transport modes reported in the repository of mobility solutions are as follows:

- Bike
- Bus
- Car
- Electric scooter (typically easy to handle, driveable with car driving licence)
- Metro
- Train
- Next generation (NG) train (trains that are technically more advanced than conventional trains, e.g. very light rail, high speed trains, Hyperloop)
- Personal air vehicle (PAV)
- Helicopter
- Plane
- Ship

3.3 Analysis of mobility cluster

Following the definition of eight distinct clusters, the mobility solutions within the DATASET2050 database (3.1 Database) are each assigned to a particular cluster. From this, a high-level overview can be obtained showing which forms of mobility are reasonably well established and which ones are still in a development phase. The "Shared Mobility", "Integrated Mobility", and "Smart Mobility" clusters each contain a high number of mobility solutions as can be seen in Figure 4.

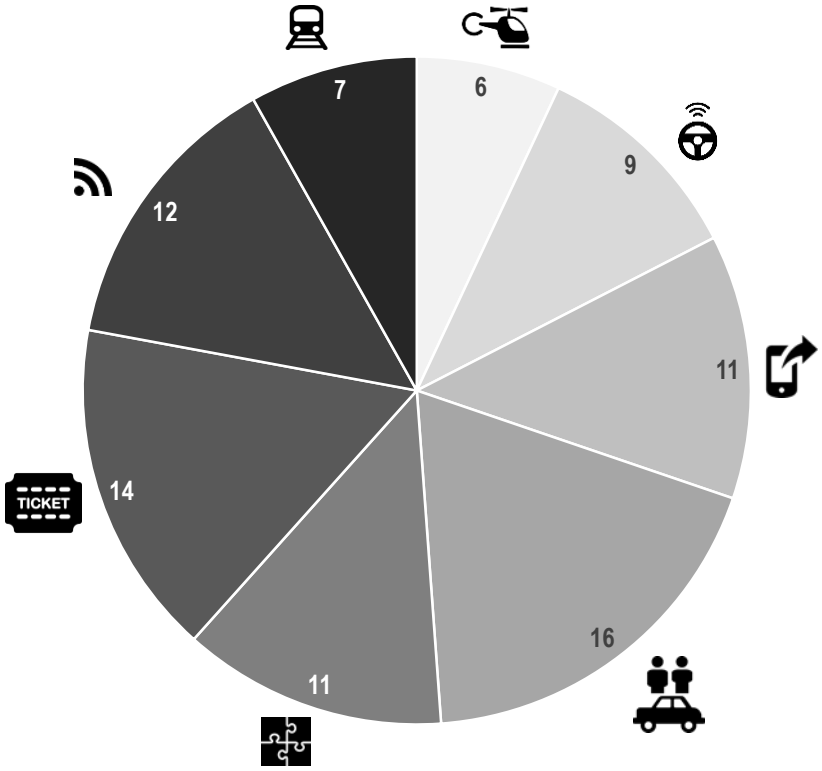


Figure 4: Number of mobility solutions within each cluster

Looking at the degree of market penetration of the different clusters, using the year of implementation as a proxy, "Shared Mobility" and "Integrated Mobility" contain mobility solutions which are well established. "Smart Mobility" and its related mobility solutions have seen an increasing application level more recently, highlighting the importance of platforms or tools for the comparison of travel options and services included. Furthermore, solutions within this cluster are easier to implement since they usually do not require a high level of investment in infrastructure or physical assets. Introducing a mobility solution within this cluster therefore may seem more feasible for providers than in those with high infrastructure requirements such as "Intermodal Mobility", for example. Two mobility solutions were already available within the "Smart Mobility" cluster in 1990. A large proportion of the mobility solutions in this cluster were already in service by 2000. On the other hand, "Autonomous Mobility" and "Piloted Flying Mobility" are clusters for which a high number of mobility solutions are predicted to be implemented from 2020 onwards. These clusters and their associated mobility solutions also have the potential to transform today's urban mobility in terms of passenger travel patterns and mode use.

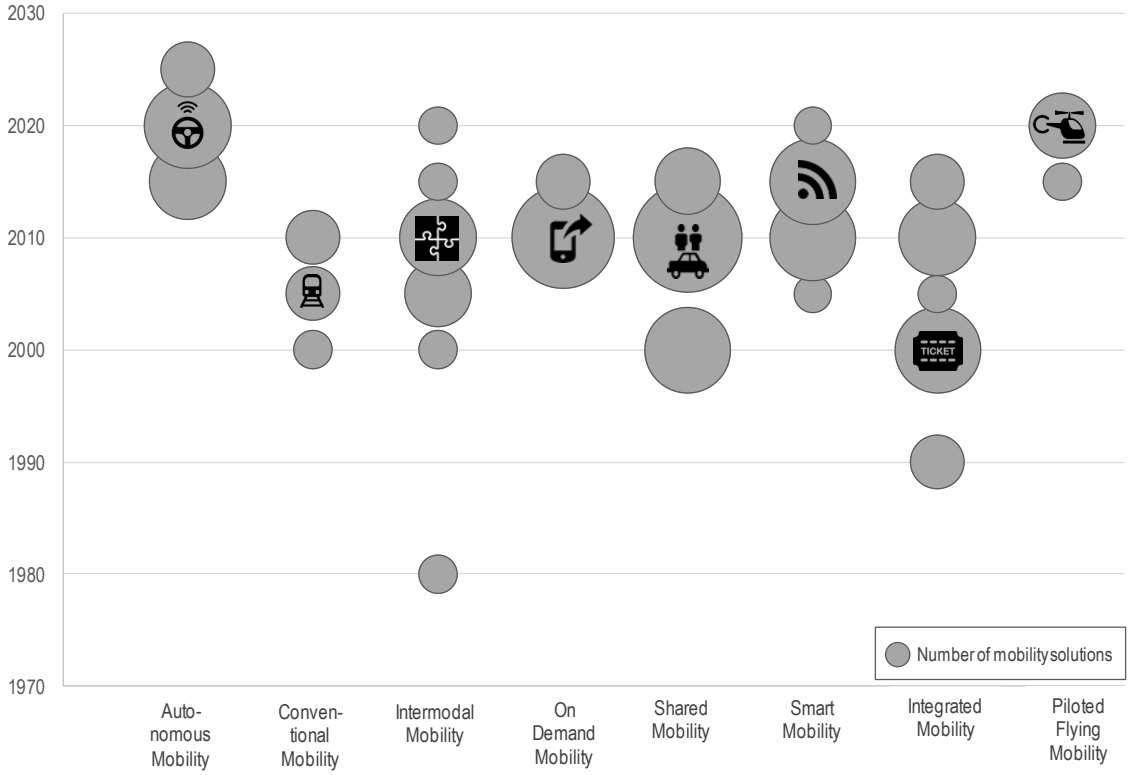


Figure 5: Market penetration of different mobility clusters

Further analysis of the different clusters with respect to the number of different modes yields an initial overview of the level of integration between different transport modes. The "Smart Mobility" and "Integrated Mobility" clusters, which are more or less independent of both infrastructure and physical assets, are the ones that integrate the highest number of modes. Since both clusters mostly apply virtual platforms to integrate different providers and users, adding another transport mode can easily be undertaken. Again, it can be seen in Figure 6 that those clusters involving actual vehicles are less likely to include a wide range of modes but rather focus on one or two, as in the "Shared Mobility", or "Conventional Mobility" clusters.

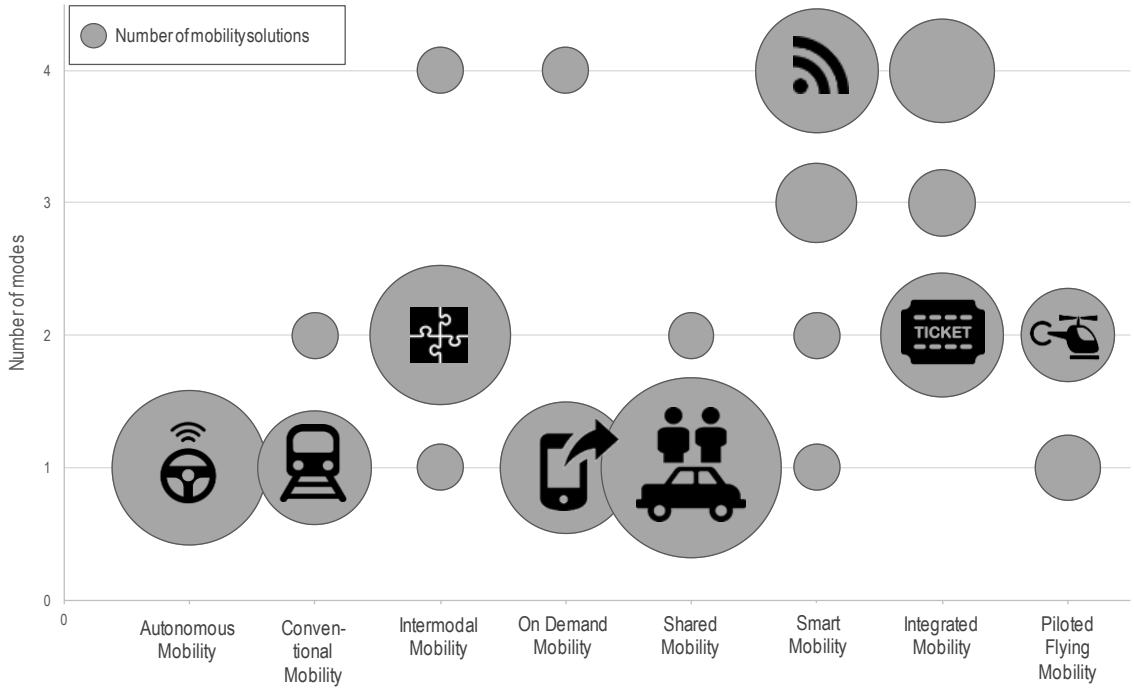


Figure 6: Number of different transport modes included within each cluster

Taking these different clusters and the respective mobility solutions into account, enables a high-level assessment according to the passenger requirements that are elaborated in Section 2. Section 4 focuses on the identification of bottlenecks and gaps with regard to passenger requirements.

3.4 Analysis of concept classes

The intention behind the definition of mobility concept classes, in addition to mobility clusters, is to break down the assessment results conducted in Section 4. Mobility clusters are assessed against previously defined passenger requirements, i.e. key passenger performance indicators, and hence gaps or well performing areas in the mobility landscape are identified. Matching these with mobility concept classes allows for a better identification of those mobility solutions to be focused on further.

Based on the repository of mobility solutions, 14 distinct classes have been developed as given in Figure 7. "Multimodal mobility" is the concept class with the most solutions whereas "Piloted air services" and "Scooter on demand" currently only contain two solutions. However, this low number does not yet say anything about the level of implementation on a global scale, there are other mobility solutions that have the same characteristics but are not included for reasons of duplication. This means that if the same solution exists in different countries but under a different name or provider, only one example is included.

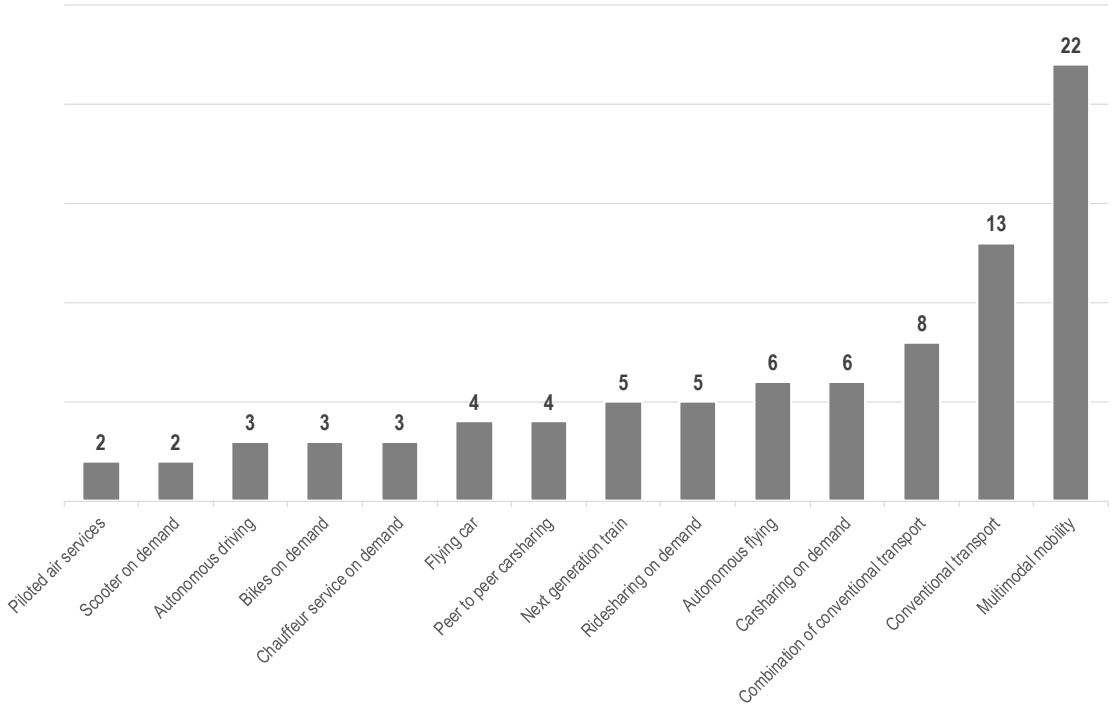


Figure 7: Number of mobility solutions within each concept class

Figure 8 shows the implementation horizons of the different concept classes: "Multimodal mobility" and the concept classes containing conventional transport solutions ("Combined conventional transport" and "Single conventional transport") often represent more traditional forms of transport and can be observed to have already been implemented before 2000. Concept classes representing sharing services (e.g. "Peer-to-peer car sharing", "Ridesharing on demand", or "Bikes on demand") have mostly emerged during the last decade. Rather visionary concept classes are "Autonomous driving", "Autonomous flying", and "Flying car". Solutions within these are currently under development and the years in Figure 8 represent estimated times of entry into service.

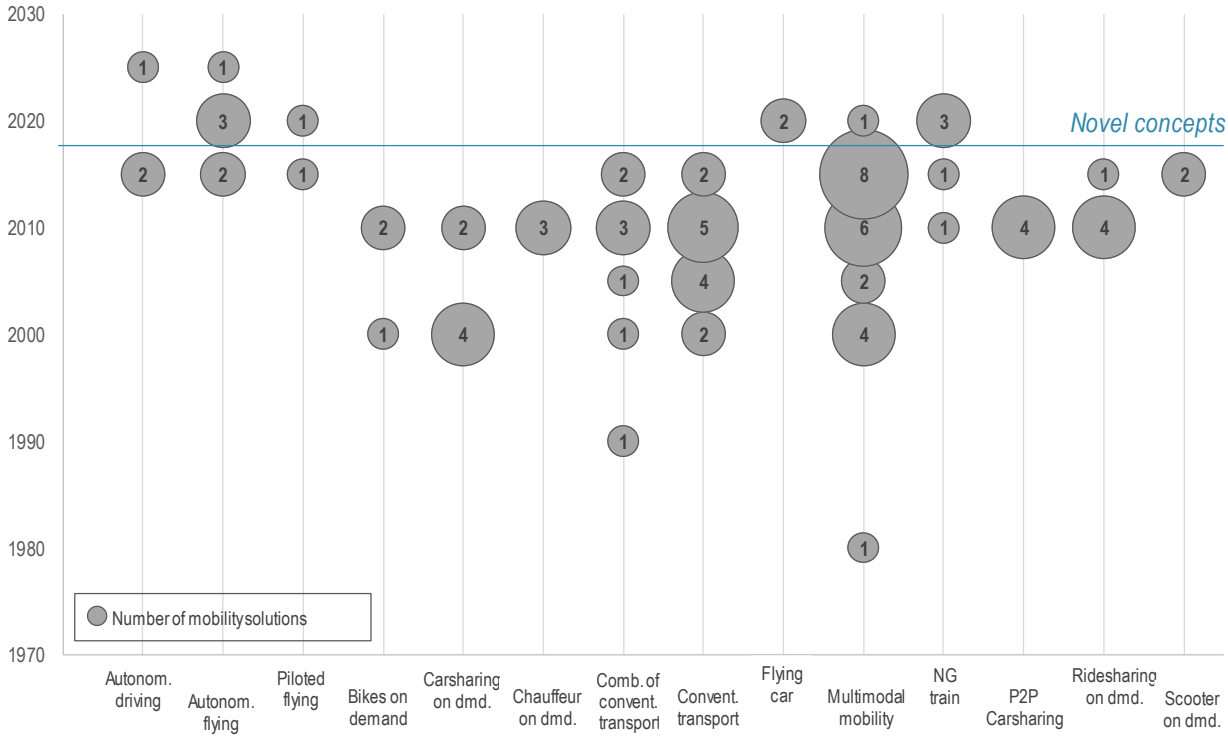


Figure 8: Development of mobility concept classes over time

The prevalence of different transport modes across mobility solutions and their development over time can be observed in the following figures. In both 2000 and 2010 the car was the dominating mode when new mobility solutions were introduced to the market. Metro, bus and train, as representatives of public transport, were also prominent during this time. In 2020, the car will only take a minor role in the development of new mobility solutions whereas the personal air vehicle (PAV), the next generation (NG) train and other public modes of transportation will gain importance. A shift away from the private car towards modes optimising available transport capacity can thus be observed.

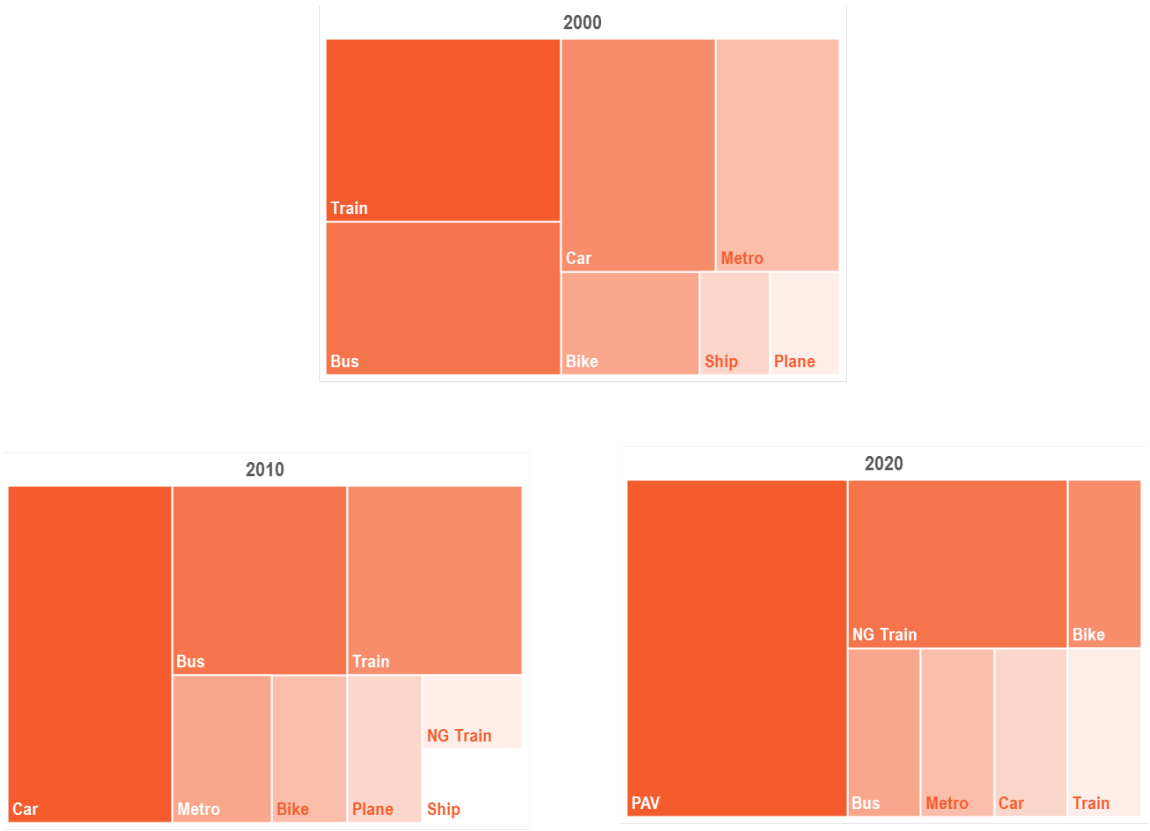


Figure 9: Prevalence of different transport modes (2000, 2010 & 2020)

4. Assessment of the European transport system

4.1 Assessment approach

For each passenger KPI in the 12 different assessment parameters, the individual clusters are ranked according to the following scheme:

- 0: The cluster does not meet this KPI, i.e. this particular passenger requirement is not fulfilled by the cluster;
- 1: The cluster partly meets this KPI, i.e. there are some drawbacks within the cluster regarding this particular requirements;
- 2: The cluster fully meets this KPI;
- n/a: The cluster does not address this particular aspect, i.e. this KPI is not within the scope of the cluster

An example of the cluster "On Demand Mobility" and the passenger assessment category "Age appropriate & accessible" is shown in Table 3.

Table 3: Example cluster “On Demand Mobility” ranking for "Age appropriate & accessible"

Category	KPIs	Ranking	Explanation
Age appropriate & accessible	short walking distance to stop	2	on-demand solution allows pick up at home (door), walking distances are thus reduced to a minimum
	possibility for pick up and stop at door	2	on-demand solution allows pick up at home (door)
	barrier-free use of mode	1	easy accessibility can vary across different transport modes provided in this cluster
	seats provided for physically impaired	1	seating availability depends on transport mode selected
	personal assistance provided	1	operator of vehicle is different from user of this service, thus assistance can be provided

4.2 Assessment of mobility clusters and respective concept classes

Following this approach, each cluster is ranked according to each passenger requirement category and the respective key performance indicators. The ranking is based on the qualitative description and the respective characteristics of each cluster, as is highlighted in the right hand column of Table 3. The example shown here is conducted for all eight clusters across the 41 predefined key performance indicators. Summing the scores for all KPIs across each cluster provides a high-level comparison of all clusters with regard to their overall performance. With a total of 41 KPIs a maximum score of 82 can be obtained, thus representing 100%.

Each cluster's score is given in Figure 10. The maximum score of 60% clearly indicates that none of them meet all passenger requirements at the same time. "On Demand Mobility" ranks highest with an overall score of 60%, followed by "Smart Mobility" and "Shared Mobility" with 51% each, and "Intermodal Mobility" with 50%. This result implies that individualised mobility solutions and the comparison of travel options seem to be best capable of meeting diverse passenger needs.

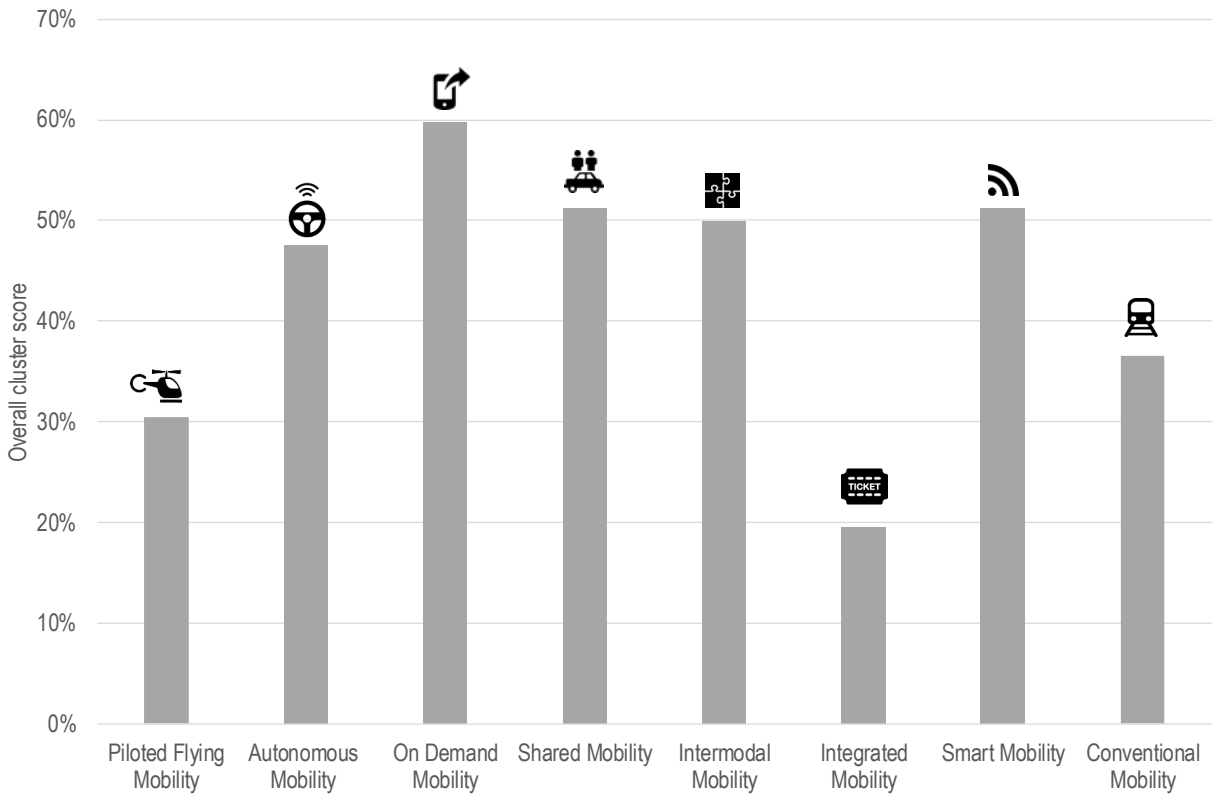


Figure 10: Overall performance of each mobility cluster

However, although a particular cluster does not rank high with regard to its overall score, it might perform well in a particular passenger requirement category such as "Age appropriate and accessible". Therefore, it is worth analysing these different categories individually and comparing clusters across these. "Piloted Flying Mobility", for example, has an overall score of only about 30% but performs best in the "Reliability" passenger requirement category since it provides passengers with the ability to access airports in a convenient way without requiring the same infrastructure as road and rail traffic.

Figure 11 shows that five of the twelve passenger requirement categories are already addressed quite well, with all of these obtaining more than 80% of the total score. In the "Available network connections" category, the "On Demand Mobility" cluster enables the transport user to adjust schedules to individual departure and arrival times and choose the respective locations accordingly. Through this, buffer times that passengers incorporate into their journey planning can be eliminated and thus the overall travel time can be reduced significantly, thus contributing to moving the European transport system closer to the 4HD2D goal. Also the "Smart Mobility" cluster enables both a reduction in and a more efficient use of overall journey time since transport options can be compared and selected according to specific travel requirements. This is also the reason why this particular cluster performs best in the "Options and control" category. In the "Reliability" category, a range of clusters meet the user requirements by providing efficient and on-time feeder services to airports as well as the possibility for increased frequencies during peak hours.

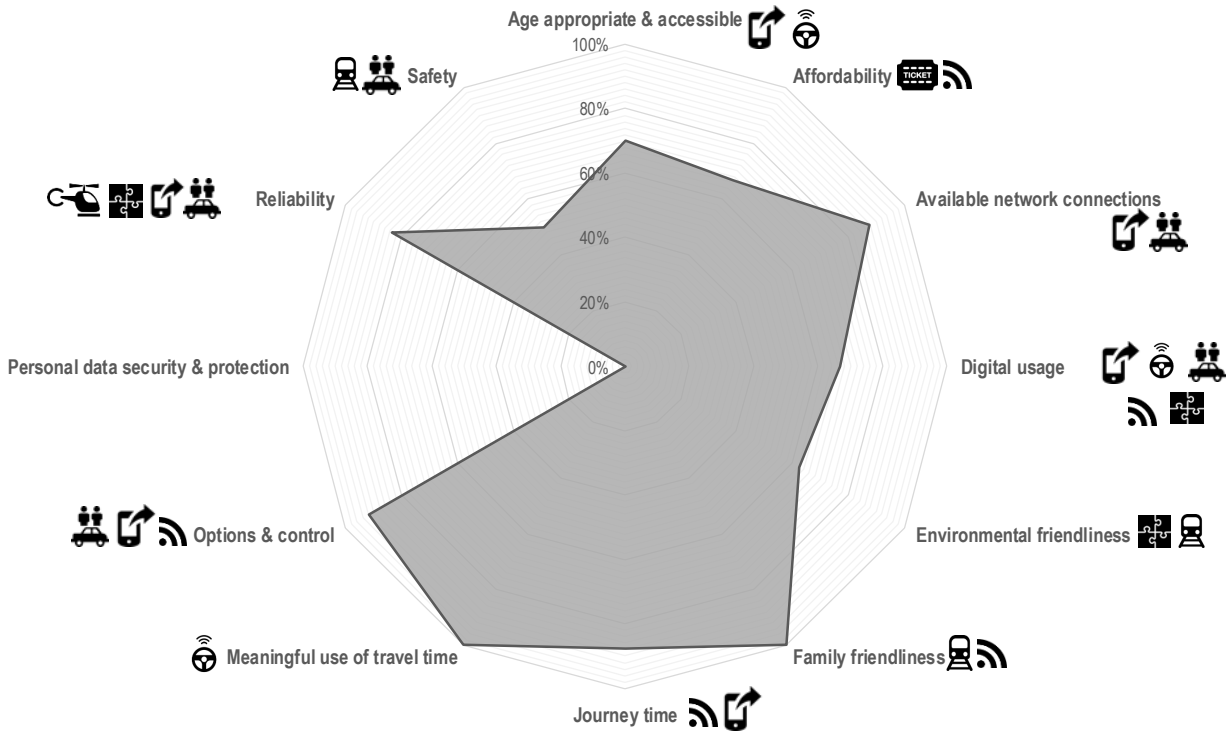


Figure 11: Mobility clusters addressing different passenger requirements

The assessment of clusters in terms of meeting passenger requirements reveals some critical gaps and bottlenecks as well. The "Personal data security and protection" category is not addressed by the considered clusters since the KPIs in this category present a level of detail which is not reported within the characterisation of the aggregated clusters. Gaining an insight into whether passenger privacy is adequately protected and whether consumer rights are adhered to requires, firstly, a definition of the relevant standards that mobility solution providers have to abide by and, in a second step, an appropriate evaluation of individual mobility solutions. The "Safety" and "Meaningful use of travel time" categories also require a more detailed insight than available at the aggregated level of the cluster characterisation. Clusters such as "On Demand Mobility", "Shared Mobility", "Intermodal Mobility", or "Piloted Flying Mobility" allow for the integration of digital services and products to provide users with different options along the journey. Providing internet accessibility in vehicles would thus allow travellers to use their time in the vehicle for work, e.g. virtual meetings or telephone conferences.

A category currently lagging behind with regard to prioritisation by mobility providers is "Environment friendliness", which includes indicators such as the availability of carbon-offsetting schemes, for example. However, since these aspects will become more important, often driven by politically induced regulation, providers of mobility solutions will be compelled to internalise negative externalities and thus adjust their products and services.

5. Identification of gaps and respective action areas

5.1 Meeting future passenger requirements

Identifying future passenger requirements and differentiating by passenger groups, which go beyond the mere distinction between business and leisure, provides the basis for detecting gaps and bottlenecks along the entire travel chain. In this regard, the derivation of passenger-centric KPIs yields a comprehensive set of assessment parameters that can be applied to assess the performance of the European transport system. The evaluation of the latter, represented by currently available as well as planned mobility solutions, thus provides a guideline to which areas require improvement and what type of mobility solutions enable enhanced passenger comfort and the potential for travel time reduction. Since the diversity and number of mobility solutions is very large, and different solutions have the same underlying concept, such as DriveNow and car2go, for example, distinct clusters have been defined which represent a particular form of mobility. By this, passenger requirements can be assessed on a high-level cluster basis, resulting in the detection of gaps and bottlenecks and hence the depiction of future investment requirements.

Based on the evaluation of these clusters, a range of high-level action areas can be identified that enable the enhancement of passenger comfort, a more efficient use of travel time and a reduction of unnecessary buffer or waiting times (Table 4). This list is not exhaustive but provides an initial overview of those aspects that current exhibit the highest improvement potential. For each of the identified gaps, action areas and thus improvement potential are proposed to address passenger requirements in a better way. In this regard, mobility solutions that incorporate barrier-free travel options and enable passengers to make use of personal assistance services need to be promoted on a larger scale to meet the demand of physically impaired passengers (such as some passengers belonging to the "Best Agers"), or of those in need of personal exchange during their journey. Related to this area is the demand for mobility services that truly cover the journey segment to the passenger’s door, e.g. an increased diversity and associated business models providing pick-up services from public transport stops to the travellers’ home. An important feature here is the potential involvement of the public, e.g. mobility exchange platforms within neighbourhoods to offer on-demand transport services, since some areas lack the provision of ubiquitous taxi services (especially in more rural areas).

Table 4: Addressing gaps and bottlenecks in the current European transport system

No.	Aggregated gaps and bottlenecks across clusters	High-level action areas
1	Lack of wide coverage of barrier-free mobility solutions and personal assistance if required	– Technical / mobility solutions providing easy vehicle access and egress – Availability of provisional personal assistance services
2	Limited availability of pick-up services at home that can be aligned with individual travel requirements	– Mobility solutions covering last mile, e.g. providing flexible coverage from door to public transport station
3	Limited provision of offsetting schemes to internalise negative externalities	– Implementation of incentive schemes to integrate negative externalities into the (transport) pricing structure – Transparent information enabling comparison of transport alternatives in terms of negative externalities, e.g. CO_2 emissions
4	Limited integration of services / products / amenities in the different vehicles, thus enabling productive travel time	– Integration of communication technologies and to provide a feasible working environment – Dedicated working or recreation space within vehicles if designed for large groups of people
5	Unnecessary buffer times during exchange between transport modes and mobility solutions	– Solutions providing real-time travel information and according alignment of travel itineraries – Dedicated interchange platforms between modes to reduce walking distances

Other action areas address the demand for the internalisation of negative externalities such as carbon emissions during a journey. Growing environmental awareness among passengers coupled with a potential increase in policy regulations can influence the choice of whether to travel and with which mobility options. Pricing schemes may therefore be required to reflect all costs associated with the journey. Furthermore, the meaningful use and possible reduction of overall travel time are important aspects to be considered in the re-shaping of the European transport system. Concerning potential travel-time savings, passengers often plan buffer times to account for potential delays or waiting time during transport-related processes or for the interchange between modes. By supplying real-time information at all times during the journey, passengers can adjust their travel plans accordingly and thus avoid these buffer times. Furthermore, shared liabilities across mobility providers enable an on-demand adjustment of passengers' travel itineraries, thus saving passengers the stress of readjusting these by themselves in case of delay or cancellation. Finally, the potential activities and services available to passengers during their travel time have a large impact on how time is valued. Being able to conduct work-related tasks during the journey and thus use this time efficiently can lead to a decrease in the value of travel time. Thus, the high emphasis placed on travel-time reduction decreases with increasing availability of services and activities during the journey.

A guide to how appropriate mobility solutions can be identified and implemented in the future in order to closing these gaps and simultaneously meet future passenger requirements is provided in Figure 12. Starting from the passenger-centric assessment parameters on the left-hand side, one can identify clusters that meet specific parameters. Having selected a particular cluster, the respective mobility concept classes are outlined on the right-hand side of the figure:

The "Shared Mobility" cluster, for example, addresses the "Reliability", "Available network of connections", "Digital usage", "Options & control" and "Safety" assessment parameters in an effective way. To get a more detailed insight into why this is the case, the corresponding mobility concept classes can be analysed in more detail:

1. The "Shared Mobility" cluster is linked to the "Carsharing on demand", "Peer to peer carsharing", "Bikes on demand" and "Scooter on demand" concept classes. All these concept classes have in common that the respective transport mode can be accessed at the time and location of travel demand.
2. An example for "Peer to peer carsharing" is the SocialCar mobility solution (see the repository in the Appendix) - a Spanish company that links car owners to users who require a car. The platform covers insurance, bookings, and capacity management based on the availability of the owners' cars.

Users can therefore access this transport mode according to their individual demand, plan in advance and thus enhance their network of connections.

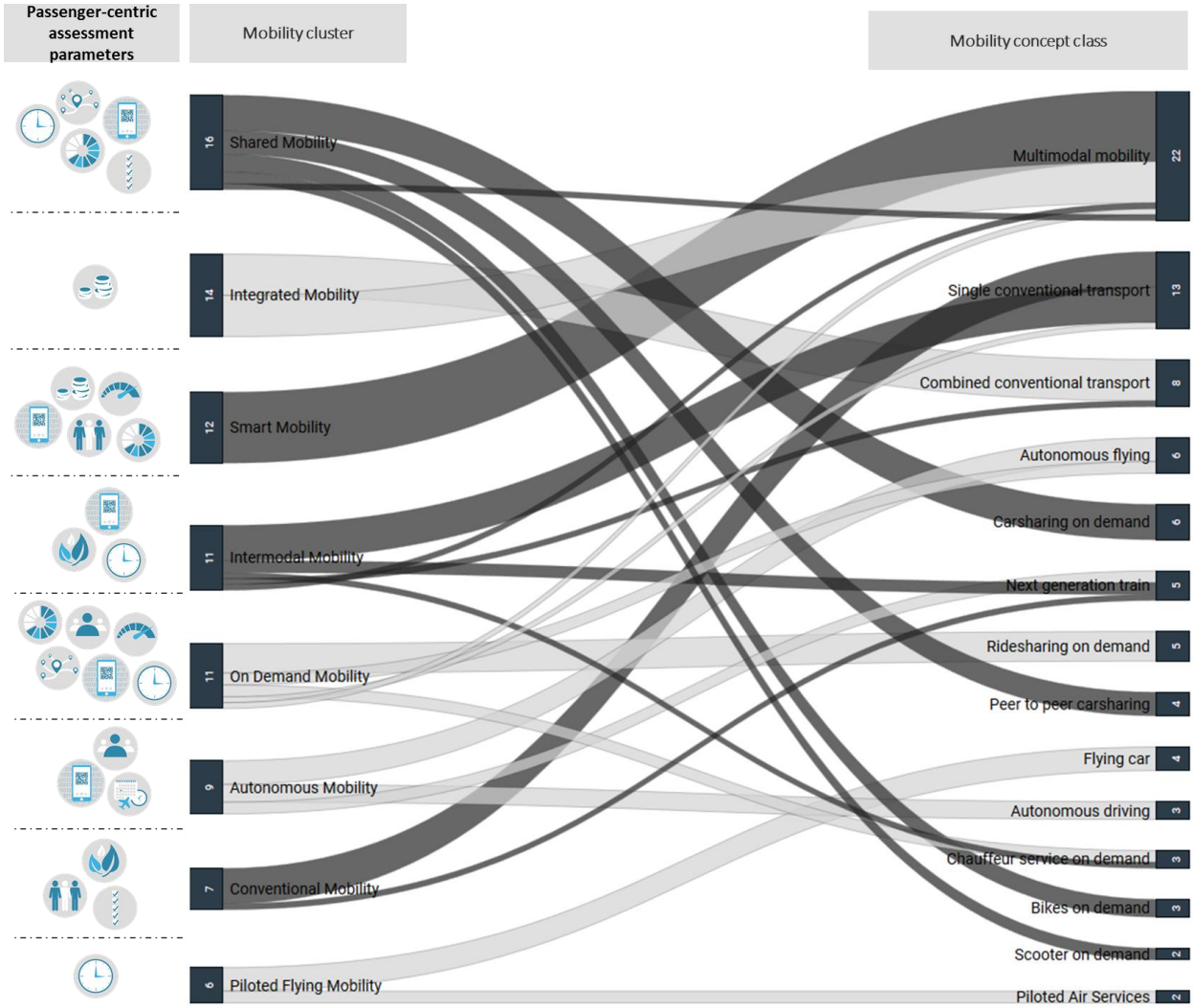


Figure 12: Mobility concept classes meeting a variety of passenger requirements

Applying this multi-level approach ensures an initial overview of current and future gaps in the (European) transport system and of how well passenger requirements are being met. Furthermore, a more detailed insight can be acquired by analysing related mobility concept classes and individual mobility solutions. By integrating the passenger perspective, the needs of particular user groups as described in the six current and six future passenger profiles can be assessed and addressed in an appropriate way.

5.2 The way towards ACARE SRIA goals

No.	Action Area	DATASET2050 contribution	Deliverables / publications
1	Understand customer, market and societal expectations and opportunities	Provision of a detailed assessment of current and future passenger demand and travel behaviour – Identification and assessment of multiple factors that influence travel demand – Derivation of six distinct current and future passenger profiles, which provide the basis for the analysis of distinct journey patterns (e.g. travel time, luggage requirements) – Development of passenger-centric and cost-centric assessment parameters, which enable the identification of physical, technological and regulatory gaps and bottlenecks the European transport system faces today and in the future	D3.1 D3.2
2	Design and implement an integrated, intermodal transport system	Repository of current and future mobility solutions enabling a more streamlined European transport system – Collection and structuring of multiple mobility solutions that address current and future passenger needs – Assessment which forms of mobility provide feasible solutions for implementation in transport system Repository of mutimodal metrics, in the context of a door-to-door approach	D5.3 D5.1
3	Develop capabilities to evaluate mobility concepts, infrastructure and performance	Development of passenger-centric and cost-centric assessment parameters with their respective KPIs, which enable the assessment and identification of gaps and bottlenecks the European transport system faces today and in the future – Definition of Key Performance Areas (KPAs) to be monitored to ensure that all aspects of mobility are understood, such as Access and Equity, Cost, Flexibility, Interoperability, Sustainability. These are based on the KPAs defined by ICAO for measuring the performance of the Air-Traffic Management system; – Development of metrics and KPIs, such as "percentage of journeys in less than 4 hours", "distance travelable in less than 4 hours", "diversity of destinations", to measure the performance of these KPAs; – Identification of further metrics and indicators that could be of further use	D5.3 D5.1
4	Provide travel management tools for informed mobility choices	The Mercury tool, central to the DATASET2050 model, represents the state of the art in European D2D mobility management, with unique, explicit passenger itineraries, combined with developing future passenger profiling and disruption assessment capabilities.	
5	Deliver mobility intelligence: journey information, data and communication	Provision of current and future journey data – Collection of European mobility data on a country level, such as trips per capita, nights spent per capita, distribution of domestic and outbound trips, average expenditure per trip per country, prevalence of air travel per country as well as forecast mobility data (average domestic RPK growth 2010-2030, forecasted air traffic development) – Derivation of five European archetype journeys and matching of these to respective current demand profiles – Development of a passenger demand model and modelling of a scenario for passenger traffic volumes for Europe (2035 & 2050)	D3.1 D3.2
6	Provide tools for system and journey	– Metrics have been defined for measuring journey resilience (e.g. under flexibility and predictability KPAs) – By design, the Mercury tool has the capability to be adapted and to assess KPIs under disruption scenarios and/or under assumptions	D5.1 D5.3

	resilience, for disruption avoidance and management	of future policy mechanisms (e.g. regarding Regulation 261 and/or integrated ticketing)	
7	Evolve airports into integrated, efficient and sustainable air transport interface nodes	Increased visibility of door-to-door multimodal metrics and KPIs in the context of EU mobility. Qualitative and quantitative insights on what is the current status and what is the expected evolution if novel concepts are implemented	D4.2 D5.2
8	Design and implement an integrated information, communication, navigation and surveillance platform	n/a	
9	Develop future air traffic management concepts and services for airspace users	Listing and documenting the novel concepts expected in the gate-to-gate segment (ATM), with a preliminary impact on future D2D mobility.	D4.2
10	Address cross-cutting issues: system intelligence, human factors and automation support, autonomy and resilience	n/a	

6. Discussion and conclusion

This DATASET2050 deliverable (D5.3) built on previous work in the project by deriving passenger-centric performance parameters based on the requirements of both current and future passenger profiles. Defining respective key performance indicators enables the assessment of both the European transport system and particular mobility solutions. In total, twelve passenger-centric assessment parameters and 41 respective key performance indicators have been developed, which cover the demand side only, hence, current and future passenger needs, wishes and requirements towards mobility.

Another main pillar of this deliverable has been the establishment of a repository of mobility solutions currently operating in the European transport system and planned to be implemented in the future. Since mobility solutions exhibit similar characteristics, these have been clustered in eight different high-level group. Each of these eight clusters represents a particular form of mobility, such as on-demand mobility, for example. The passenger-centric KPIs have been applied in the structural assessment of these high-level mobility clusters. Each cluster has been ranked separately, providing a high-level comparison of all clusters with regard to their overall performance. The main findings include:

- "On Demand Mobility" ranks highest with an overall score of meeting 60% of the passenger-centric KPIs. This particular cluster contains mobility solutions from autonomous flying vehicles (e.g. Uber, e-volo), chauffeur on demand services (e.g. Blacklane), or multimodal mobility solutions (e.g. Tuup) which all respond well to passengers wanting to be flexible, having individual schedules, and adjusting the transport solution to their current needs.
- "Smart Mobility" and "Shared Mobility" also have a high overall score with 51% each, and "Intermodal Mobility" with 50%. The mobility solutions within each of these clusters meet passenger needs for a seamless and reliable journey. Planning can be conducted according to individual requirements and travel itineraries potentially aligned, due to disruptions along the journey, for example.

Although a particular cluster does not rank high with regard to its overall score, it might perform well in a particular passenger requirement category. Among other findings, results imply that individualised mobility solutions and the comparison of travel options seem to be best capable of meeting diverse passenger needs.

In addition, the assessment of clusters in terms of meeting passenger requirements reveals critical gaps and bottlenecks as well:

- The "Personal data security and protection" category is not addressed by the considered clusters since the KPIs in this category present a level of detail, which is not reported within the characterisation of the aggregated clusters.
- Another category currently lagging behind with regard to prioritisation by mobility providers is "Environment friendliness", such as by providing carbon-offset schemes for passengers.

Overall, mobility solutions that incorporate barrier-free travel options and enable passengers to make use of personal assistance services need to be promoted on a larger scale to meet the demand of physically impaired passengers. The analysis also identified the limited availability of pick-up services at home, limited integration of services, products or other amenities in the different vehicles, enabling productive travel time or the reduction of buffer time during exchange between transport modes and mobility solutions.

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8. Acronyms and abbreviations

- ACARE: Advisory Council for Aviation Research and Innovation in Europe
- BHL: Short name of DATASET2050 partner: Bauhaus Luftfahrt
- CSA: Coordination and Support Action
- D: Deliverable
- D2D: Door-to-door (mobility concept)
- DATASET2050: Data-driven approach for a seamless efficient travelling in 2050
- EFTA: European Free Trade Association (EFTA member countries are Iceland, Liechtenstein, Norway and Switzerland)
- EU: European Union
- EU-28: European Union 28 member countries (since July 2013)
- G2G: Gate-to-gate
- GDP: Gross domestic product
- H2020: Horizon 2020 research programme
- ICT: information and communications technology
- INX: Short name of DATASET2050 coordinator: Innaxis
- KPI: Key performance indicator
- NG: Next generation
- PAV: Personal air vehicle
- PI: Performance indicator
- SRIA: Strategic research and innovation agenda
- VOT: Value of travel time
- WP: Work package
- 4HD2D: Four-hour door-to-door

Appendix I. Overview Mobility Cluster

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/Visionary (2)	Implementation
1	Urban Flying	voom	on-demand helicopter booking platform/service	Voom	1	Aviation	3	Helicopter	National	0	2017
1	Urban Flying	zee aero	Flying car concepts	Zee Aero	2	Flying Car	8	PAV	Visionary	2	N/A
1	Urban Flying	Joby Aviation	Aerospace Industry	S2, Lotus, Leaptech	1	Aviation	3	PAV	Visionary	2	2020
1	Urban Flying	PAL-V International	Flying car, manually handled	PAL-V Liberty	2	Flying Car	8	PAV	Visionary	2	2018
1	Urban Flying	Terrafugia	Flying car, manually handled	The Transition	2	Flying Car	8	PAV	Visionary	2	2020
1	Urban Flying	Terrafugia	Flying car, manually handled	TF-X™	2	Flying Car	8	PAV	Visionary	2	N/A
2	Autonomous mobility	airbus	Aerospace Industry	Vahana	1	Autonomous flying	2	PAV	Visionary	2	2020
2	Autonomous mobility	Lilium GmbH	on-demand, autonomous VTOL air taxis	Lilium Jet	1	Autonomous flying	2	PAV	Visionary	2	2025

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
2	Autonomous mobility	Urban Aeronautics	autonomous VTOL air vehicle for complex urban and natural environments	Airmule	1	Autonomous flying	2	PAV	Visionary	2	2022
2	Autonomous mobility	Ehang	tech company of intelligent aerial vehicles	Ehang 184	1	Autonomous flying	2	PAV	Visionary	2	2017
2	Autonomous mobility	Waymo	successor of google car, providing self-driving cars	Waymo	1	Autonomous driving	1	Car	Visionary	2	2017
2	Autonomous mobility	Volkswagen Group	On demand autonomous car transport	Sedrik	1	Autonomous driving	1	Car	Visionary	2	2027
2	Autonomous mobility	Hyperloop One	high speed transport company	Hyperloop One	1	Next Generation Train	13	NG Train	Visionary	2	2017: Testing/ Planned for: 2020(freight) / 2021(passengers)
2	Autonomous mobility	The Boring Company	Elon Musk founded, faster urban transit via tunnels	The Boring Company, TBC	1	Next Generation Train	13	NG Train	National	0	2018
2	Autonomous mobility	Olli	on-demand autonomous bus transport	Olli	1	Autonomous driving	1	Bus	Visionary	2	2017

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
3	On demand mobility	e-volo	on-demand, autonomous VTOL air taxis	Volocopter	1	Autonomous flying	2	PAV	Visionary	2	2017
3	On demand mobility	Uber	on-demand, autonomous VTOL air taxis	N/A	1	Autonomous flying	2	PAV	Visionary	2	2020
3	On demand mobility	Rally Bus	Social Mobility Network, organized bus travels to events	Rally Bus	1	Conventional Transport	7	Bus	National	0	2013
3	On demand mobility	Lyft	On-demand ridesharing network	Lyft	1	Ridesharing on demand	11	Car	National	0	2012
3	On demand mobility	Cabify	On-demand ridesharing network	Cabify	1	Ridesharing on demand	11	Car	International	1	2011
3	On demand mobility	Gett	On-demand ridesharing network	Gett	1	Ridesharing on demand	11	Car	International	1	2010
3	On demand mobility	Tuup	Compares and displays and books various mobility options	Tuup	4	Multimodal mobility	9	Bus	National	0	2015
3	On demand mobility	Tuup	Compares and displays and books various mobility options	Tuup		Multimodal mobility	9	Train	National		2015
3	On demand mobility	Tuup	Compares and displays and books various mobility options	Tuup		Multimodal mobility	9	Car	National		2015

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
3	On demand mobility	Tuup	Compares and displays and books various mobility options	Tuup		Multimodal mobility	9	Bike	National		2015
3	On demand mobility	Allygator	On-demand ridesharing network	Allygator	1	Ridesharing on demand	11	Bus	National	0	2016
3	On demand mobility	Sixt	On-demand chauffeur service	myDriver	1	Chauffeur service on demand	5	Car	International	1	2012
3	On demand mobility	Blacklane	On-demand chauffeur service	Blacklane	1	Chauffeur service on demand	5	Car	National	0	2011
3	On demand mobility	Uber	On-demand ridesharing network	Uber	1	Ridesharing on demand	11	Car	International	1	2009
4	Shared Mobility	Yugo	E-Scooter Sharing company	Yugo	1	Scooter on demand	12	Electric Scooter	National	0	2016
4	Shared Mobility	Emmy-Sharing	E-Scooter Sharing company	Emmy	1	Scooter on demand	12	Electric Scooter	National	0	2015
4	Shared Mobility	Drivy	private car sharing company	Drivy	1	Peer to Peer Carsharing	10	Car	International	1	2010
4	Shared Mobility	car2go	On demand carsharing	Car2Go	1	Carsharing on demand	4	Car	International	1	2008

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
4	Shared Mobility	Stadtmobil	On demand carsharing	Stadtmobil	1	Carsharing on demand	4	Car	National	0	1999
4	Shared Mobility	SnappCar	private car sharing company	SnappCar	1	Peer to Peer Carsharing	10	Car	National	0	2011
4	Shared Mobility	me mobility	Compares and displays various car sharing options	me mobility	1	Multimodal mobility	9	Car	National	0	2014
4	Shared Mobility	Cambio	On demand carsharing	Cambio	1	Carsharing on demand	4	Car	International	1	2000
4	Shared Mobility	Deutsche Bahn	German railway Company (DB)	Flinkster	1	Carsharing on demand	4	Car	National	0	2001
4	Shared Mobility	Avis	car sharing company	Zipcar	1	Carsharing on demand	4	Car	National	0	1999
4	Shared Mobility	SocialCar	private car sharing company	SocialCar	1	Peer to Peer Carsharing	10	Car	National	0	2011
4	Shared Mobility	Turo	private car sharing company	Turo	1	Peer to Peer Carsharing	10	Car	International	1	2009
4	Shared Mobility	DriveNow	On demand carsharing	DriveNow	1	Carsharing on demand	4	Car	International	1	2011
4	Shared Mobility	Deutsche Bahn	railway company	DB Bike	1	Bikes on demand	14	Bike	National	0	2000

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/Visionary (2)	Implementation
4	Shared Mobility	Londoncitybike	Bikesharing company London	Londoncitybike	1	Bikes on demand	14	Bike	National	0	2007
4	Shared Mobility	velib	Bikesharing company Paris	velib	1	Bikes on demand	14	Bike	National	0	2007
5	Intermodal Mobility	Ferrara Bus & Fly	Airport Shuttle from Ferrara to Bologna	Ferrara Bus & Fly	2	Conventional Transport	7	Bus	National	0	2011
5	Intermodal Mobility	Airport Shuttle Munich	Airport Shuttle to Munich Airport	Airport Shuttle Munich	2	Conventional Transport	7	Bus	National	0	2000
5	Intermodal Mobility	AirportLiner	(individual) Airport Shuttle from Lower Bavaria to MUC	AirportLiner	2	Conventional Transport	7	Bus	National	0	2006
5	Intermodal Mobility	busandfly	Shuttle from Bavaria to all bavarian airports	busandfly	2	Conventional Transport	7	Bus	National	0	2003
5	Intermodal Mobility	Lufthansa	Door2 Door Transport Concept	Lufthansa Express Transport	4	Multimodal mobility	9	Train	International	1	1982
5	Intermodal Mobility	Lufthansa	Door2 Door Transport Concept	Lufthansa Express Transport		Multimodal mobility	9	Bus	International	1	1982
5	Intermodal Mobility	Lufthansa	Door2 Door Transport Concept	Lufthansa Express Transport		Multimodal mobility	9	Car	International	1	1982

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
5	Intermodal Mobility	Lufthansa	Door2 Door Transport Concept	Lufthansa Express Transport		Multimodal mobility	9	Helicopter	International	1	1982
5	Intermodal Mobility	BayShuttle	high speed boat transfer to airport	BayShuttle	2	Combination of conventional transport	6	Ship	National	0	2006
5	Intermodal Mobility	BayShuttle	high speed boat transfer to airport	BayShuttle		Combination of conventional transport	6	Bus	National	0	2006
5	Intermodal Mobility	Cotai Water Jet Airport Express	high speed ferry service to airport	Cotai Water Jet Airport Express	2	Conventional Transport	7	Ship	National	0	2007
5	Intermodal Mobility	CKS Airport Express	Taipe airport express high speed transrapid train	CKS Airport Express	2	Next Generation Train	13	NG Train	National	0	2017
5	Intermodal Mobility	ULTra (Urban Light Transit)	Personal Rapid Transit system autonomously operated.	ULTra	1	Next Generation Train	13	NG Train	National	0	2011
5	Intermodal Mobility	Southend Airport Railway Station	City Transfer to Airport	Southend Airport Railway Station	2	Conventional Transport	7	Train	National	0	2011

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5	Intermodal Mobility	Mozio	24/7 door2airport/ airport2door service	Mozio	2	Chauffeur service on demand	5	Car	International	1	2012
6	Ticket & Mode integration	Hongkong Octopus Card	smart card payment system	Octopus Card	3	Multimodal mobility	9	Train	National	0	1997
6	Ticket & Mode integration	Hongkong Octopus Card	smart card payment system	Octopus Card		Multimodal mobility	9	Bus	National	0	1997
6	Ticket & Mode integration	Hongkong Octopus Card	smart card payment system	Octopus Card		Multimodal mobility	9	Metro	National	0	1997
6	Ticket & Mode integration	Oyster Card	smart card payment system	Oyster Card	4	Multimodal mobility	9	Bus	National	0	2003
6	Ticket & Mode integration	Oyster Card	smart card payment system	Oyster Card		Multimodal mobility	9	Train	National	0	2003
6	Ticket & Mode integration	Oyster Card	smart card payment system	Oyster Card		Multimodal mobility	9	Metro	National	0	2003
6	Ticket & Mode integration	Oyster Card	smart card payment system	Oyster Card		Multimodal mobility	9	Ship	National	0	2003

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6	Ticket & Mode integration	Deutsche Bahn	all in one ticket (shut down 11/2016)	touch & travel	4	Multimodal mobility	9	Train	National	0	2011
6	Ticket & Mode integration	Deutsche Bahn	all in one ticket (shut down 11/2016)	touch & travel		Multimodal mobility	9	Bus	National	0	2011
6	Ticket & Mode integration	Deutsche Bahn	all in one ticket (shut down 11/2016)	touch & travel		Multimodal mobility	9	Metro	National	0	2011
6	Ticket & Mode integration	üstra	combined card for public transport, car sharing & train	HannoverMobil	4	Multimodal mobility	9	Bus	National	0	2004
6	Ticket & Mode integration	üstra	combined card for public transport, car sharing & train	HannoverMobil		Multimodal mobility	9	Train	National	0	2004
6	Ticket & Mode integration	üstra	combined card for public transport, car sharing & train	HannoverMobil		Multimodal mobility	9	Car	National	0	2004
6	Ticket & Mode integration	üstra	combined card for public transport, car sharing & train	HannoverMobil		Multimodal mobility	9	Metro	National	0	2004

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6	Ticket & Mode integration	Clipper	Metropolitan Transportation Commission (**MTC**) - government agency	Clipper	4	Multimodal mobility	9	Metro	National	0	2010
6	Ticket & Mode integration	Clipper	Metropolitan Transportation Commission (**MTC**) - government agency	Clipper		Multimodal mobility	9	Bus	National	0	2010
6	Ticket & Mode integration	Clipper	Metropolitan Transportation Commission (**MTC**) - government agency	Clipper		Multimodal mobility	9	Train	National	0	2010
6	Ticket & Mode integration	Clipper	Metropolitan Transportation Commission (**MTC**) - government agency	Clipper		Multimodal mobility	9	Bike	National	0	2010
6	Ticket & Mode integration	mobilitymix	combined card for public transport, car sharing, train and payment	mobilitymix	4	Multimodal mobility	9	Train	National	0	2002
6	Ticket & Mode integration	mobilitymix	combined card for public transport, car sharing, train and payment	mobilitymix		Multimodal mobility	9	Bus	National	0	2002

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6	Ticket & Mode integration	mobilitymix	combined card for public transport, car sharing, train and payment	mobilitymix		Multimodal mobility	9	Metro	National	0	2002
6	Ticket & Mode integration	mobilitymix	combined card for public transport, car sharing, train and payment	mobilitymix		Multimodal mobility	9	Car	National	0	2002
6	Ticket & Mode integration	mobilitymix	combined card for public transport, car sharing, train and payment	mobilitymix		Multimodal mobility	9	Bike	National	0	2002
6	Ticket & Mode integration	SmarTrip	One Card for Train, Metro & Bus in Washington	SmarTrip	3	Multimodal mobility	9	Train	National	0	1999
6	Ticket & Mode integration	SmarTrip	One Card for Train, Metro & Bus in Washington	SmarTrip		Multimodal mobility	9	Metro	National	0	1999
6	Ticket & Mode integration	SmarTrip	One Card for Train, Metro & Bus in Washington	SmarTrip		Multimodal mobility	9	Bus	National	0	1999
6	Ticket & Mode integration	biketrainbike	Door2Door via Bike, Train, Bike	BiTiBi- Bike Train Bike	2	Combination of conventional transport	6	Train	National	0	2014

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
6	Ticket & Mode integration	biketrainbike	Door2Door via Bike, Train, Bike	BiTiBi- Bike Train Bike		Combination of conventional transport	6	Bike	National	0	2014
6	Ticket & Mode integration	Deutsche Bahn	Ticket combines Flight + Train	AIRail Service	2	Combination of conventional transport	6	Train	National	0	2001
6	Ticket & Mode integration	Deutsche Bahn	Ticket combines Flight + Train	AIRail Service		Combination of conventional transport	6	Plane	National	0	2001
6	Ticket & Mode integration	Deutsche Bahn	Ticket combines Flight + Train	Rail & Fly	2	combination of conventional transport	6	Train	National	0	1992
6	Ticket & Mode integration	Deutsche Bahn	Ticket combines Flight + Train	Rail & Fly		combination of conventional transport	6	Plane	National	0	1992
6	Ticket & Mode integration	SBB	national railway system	SwissPass- Mobility	2	combination of conventional transport	6	Train	National	0	2010

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6	Ticket & Mode integration	SBB	national railway system	SwissPass- Mobility		combination of conventional transport	6	Car	National	0	2010
6	Ticket & Mode integration	ÖBB	national railway system	Rail&Drive	2	combination of conventional transport	6	Train	National	0	2017
6	Ticket & Mode integration	ÖBB	national railway system	Rail&Drive		combination of conventional transport	6	Car	National	0	2017
6	Ticket & Mode integration	Deutsche Bahn	railway company	City Ticket	2	Combination of conventional transport	6	Train	National	0	2003
6	Ticket & Mode integration	Deutsche Bahn	railway company	City Ticket		Combination of conventional transport	6	Metro	National	0	2003
6	Ticket & Mode integration	Iberia	One Ticket for Bus and Flight	Bus and Fly	2	Combination of conventional transport	6	Bus	National	0	2012

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
6	Ticket & Mode integration	Iberia	One Ticket for Bus and Flight	Bus and Fly		Combination of conventional transport	6	Plane	National	0	2012
7	Smart Mobility	CarTrawler	B2B Multimodal mobility Concepts	CarTrawler	3	Multimodal mobility	9	Car	International	1	2017
7	Smart Mobility	CarTrawler	B2B Multimodal mobility Concepts	CarTrawler		Multimodal mobility	9	Plane	International	1	2017
7	Smart Mobility	CarTrawler	B2B Multimodal mobility Concepts	CarTrawler		Multimodal mobility	9	Train	International	1	2017
7	Smart Mobility	Free2Move	Compares and books all current carsharing providers	Free2Move	1	Multimodal mobility	9	Car	International	1	2016
7	Smart Mobility	9292	Travel information provider	9292 Travel	2	Multimodal mobility	9	Train	National	0	2013
7	Smart Mobility	9292	Travel information provider	9292 Travel		Multimodal mobility	9	Bus	National	0	2013
7	Smart Mobility	Citymapper	App comparing ways to get from A to B in a city	Citymapper	4	Multimodal mobility	9	Bus	International	1	2014
7	Smart Mobility	Citymapper	App comparing ways to get from A to B in a city	Citymapper		Multimodal mobility	9	Metro	International	1	2014

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/Visionary (2)	Implementation
7	Smart Mobility	Citymapper	App comparing ways to get from A to B in a city	Citymapper		Multimodal mobility	9	Bike	International	1	2014
7	Smart Mobility	Citymapper	App comparing ways to get from A to B in a city	Citymapper		Multimodal mobility	9	Car	International	1	2014
7	Smart Mobility	Google	App comparing ways to get from A to B	GoogleMaps	4	Multimodal mobility	9	Car	International	1	2005
7	Smart Mobility	Google	App comparing ways to get from A to B	GoogleMaps		Multimodal mobility	9	Bike	International	1	2005
7	Smart Mobility	Google	App comparing ways to get from A to B	GoogleMaps		Multimodal mobility	9	Bus	International	1	2005
7	Smart Mobility	Google	App comparing ways to get from A to B	GoogleMaps		Multimodal mobility	9	Train	International	1	2005
7	Smart Mobility	Google	App comparing ways to get from A to B	GoogleMaps		Multimodal mobility	9	Metro	International	1	2005
7	Smart Mobility	Google	App comparing ways to get from A to B	GoogleMaps		Multimodal mobility	9	Plane	International	1	2005
7	Smart Mobility	urban pulse	Smart App displaying fastest way to get from A to B	Urban Pulse	4	Multimodal mobility	9	Train	National	0	2011

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
7	Smart Mobility	urban pulse	Smart App displaying fastest way to get from A to B	Urban Pulse		Multimodal mobility	9	Bus	National	0	2011
7	Smart Mobility	urban pulse	Smart App displaying fastest way to get from A to B	Urban Pulse		Multimodal mobility	9	Metro	National	0	2011
7	Smart Mobility	mycicero	App for multimodal public transport, ticketing and payment	mycicero	4	Multimodal mobility	9	Bus	National	0	2015
7	Smart Mobility	mycicero	App for multimodal public transport, ticketing and payment	mycicero		Multimodal mobility	9	Train	National	0	2015
7	Smart Mobility	mycicero	App for multimodal public transport, ticketing and payment	mycicero		Multimodal mobility	9	Metro	National	0	2015
7	Smart Mobility	mycicero	App for multimodal public transport, ticketing and payment	mycicero		Multimodal mobility	9	Car	National	0	2015
7	Smart Mobility	GoEuro	Search engine comparing Bus, Trains and Flights	GoEuro	3	Multimodal mobility	9	Bus	International	1	2011
7	Smart Mobility	GoEuro	Search engine comparing Bus, Trains and Flights	GoEuro		Multimodal mobility	9	Train	International	1	2011

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/ Visionary (2)	Implementation
7	Smart Mobility	GoEuro	Search engine comparing Bus, Trains and Flights	GoEuro		Multimodal mobility	9	Plane	International	1	2011
7	Smart Mobility	Siemens	Integrated Mobility Concepts, optimized for travellers, operators and city council authorities	SiMobility	4	Multimodal mobility	9	Metro	National	0	2018
7	Smart Mobility	Siemens	Integrated Mobility Concepts, optimized for travellers, operators and city council authorities	SiMobility		Multimodal mobility	9	Car	National	0	2018
7	Smart Mobility	Siemens	Integrated Mobility Concepts, optimized for travellers, operators and city council authorities	SiMobility		Multimodal mobility	9	Bus	National	0	2018
7	Smart Mobility	Siemens	Integrated Mobility Concepts, optimized for travellers, operators and city council authorities	SiMobility		Multimodal mobility	9	Train	National	0	2018
7	Smart Mobility	Siemens	Integrated Mobility Concepts, optimized	SiMobility		Multimodal mobility	9	Bike	National	0	2018

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/Visionary (2)	Implementation
			for travellers, operators and city council authorities								
7	Smart Mobility	Daimler	App comparing ways to get from A to B in a city	Moovel	4	Multimodal mobility	9	Car	National	0	2012
7	Smart Mobility	Daimler	App comparing ways to get from A to B in a city	Moovel		Multimodal mobility	9	Bus	National	0	2012
7	Smart Mobility	Daimler	App comparing ways to get from A to B in a city	Moovel		Multimodal mobility	9	Train	National	0	2012
7	Smart Mobility	Daimler	App comparing ways to get from A to B in a city	Moovel		Multimodal mobility	9	Metro	National	0	2012
7	Smart Mobility	Ally	App comparing ways to get from A to B in a city	Ally	4	Multimodal mobility	9	Car	National	0	2014
7	Smart Mobility	Ally	App comparing ways to get from A to B in a city	Ally		Multimodal mobility	9	Bus	National	0	2014
7	Smart Mobility	Ally	App comparing ways to get from A to B in a city	Ally		Multimodal mobility	9	Train	National	0	2014

Cluster Class	Cluster	Provider or company	Project Description	Project Name	Mode(s)	Concept	Concept Class	Transport mode	Nature	National(0)/International(1)/Visionary (2)	Implementation
7	Smart Mobility	Ally	App comparing ways to get from A to B in a city	Ally		Multimodal mobility	9	Metro	National	0	2014
7	Smart Mobility	rome2rio	Travel Search engine comparing Bus, Trains and Flights	rome2rio	3	Multimodal mobility	9	Bus	International	1	2010
7	Smart Mobility	rome2rio	Travel Search engine comparing Bus, Trains and Flights	rome2rio		Multimodal mobility	9	Train	International	1	2010
7	Smart Mobility	rome2rio	Travel Search engine comparing Bus, Trains and Flights	rome2rio		Multimodal mobility	9	Plane	International	1	2010
8	Conventional Mob-Con	Flixbus	Cheap Bus provider connecting all major european cities	Flixbus	1	Conventional Transport	7	Bus	National		2013
8	Conventional Mob-Con	Amtrak	railroad service company	Amtrak	2	Conventional Transport	7	Train	National	0	2004
8	Conventional Mob-Con	Amtrak	railroad service company	Amtrak		Conventional Transport	7	Bus	National	0	2004
8	Conventional Mob-Con	JFK Airtrain	Elevated railway in NYC, connecting JFK with 10 stations	Airtrain	1	Conventional Transport	7	Train	National	0	2003

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8	Conventional Mob-Con	Network Rail	European Rail Infrastructure Managers	Network Rail	1	Conventional Transport	7	Train	National	0	2002
8	Conventional Mob-Con	Taiwan High Speed Rail Cooperation	operating and managing company of high-speed railway system	Taiwan High Speed Rail	1	Conventional Transport	7	NG Train	National	0	2011
8	Conventional Mob-Con	Thalys	european High Speed Train	Thalys	1	Conventional Transport	7	Train	National	0	2011
8	Conventional Mob-Con	University of Warwick	More efficient Railway due to less weight on rails	Very light Rail	1	Next Generation Train	13	NG Train	Visionary	2	2018