D2.1 – Establishment of Performance Framework

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Executive summary

The analysis of various European mobility strategies shows that each transport sector places increasing importance on the intermodal alignment between different stakeholders. Therefore, within CAMERA the focus is not solely placed on the aviation sector but also considers the mobility goals established in other transport sectors. The objective of Deliverable D2.1 of the CAMERA H2020 CSA project is the development of a performance framework that provides a comprehensive method of analysing European mobility strategies and the resulting goals that have to be met by the future transport system. By this, the assessment of these future goals is facilitated, enabling the measurement of the impact of different research and innovation initiatives in the field of mobility (and beyond).

For this purpose, the CAMERA performance framework has been developed by addressing European mobility goals, integrating feedback and expertise of experts from various (mobility) sectors as well as drawing on existing projects that measure the progress towards particular challenges in the European transport sector. As a result, a set of key performance indicators has been established that facilitates the assessment of gaps and bottlenecks in regard to future transport goals. These indicators provide the basis for the subsequent work in CAMERA, enabling the identification of future research and innovation needs in different areas.

1 Introduction

1.1 Objectives of the deliverable

The purpose of this deliverable is:

- to provide a comprehensive method of analysing European mobility strategies and the resulting goals that have to be met by the future transport system;
- to develop a performance framework that facilitates the assessment of these future goals, enabling the impact of different research and innovation initiatives in the field of mobility (and beyond) to be measured.

The performance framework developed by the CAMERA project is a conceptual approach that facilitates the measurement of progress towards European mobility goals. The development of this framework is organised into four consecutive steps which are depicted in Figure 1.

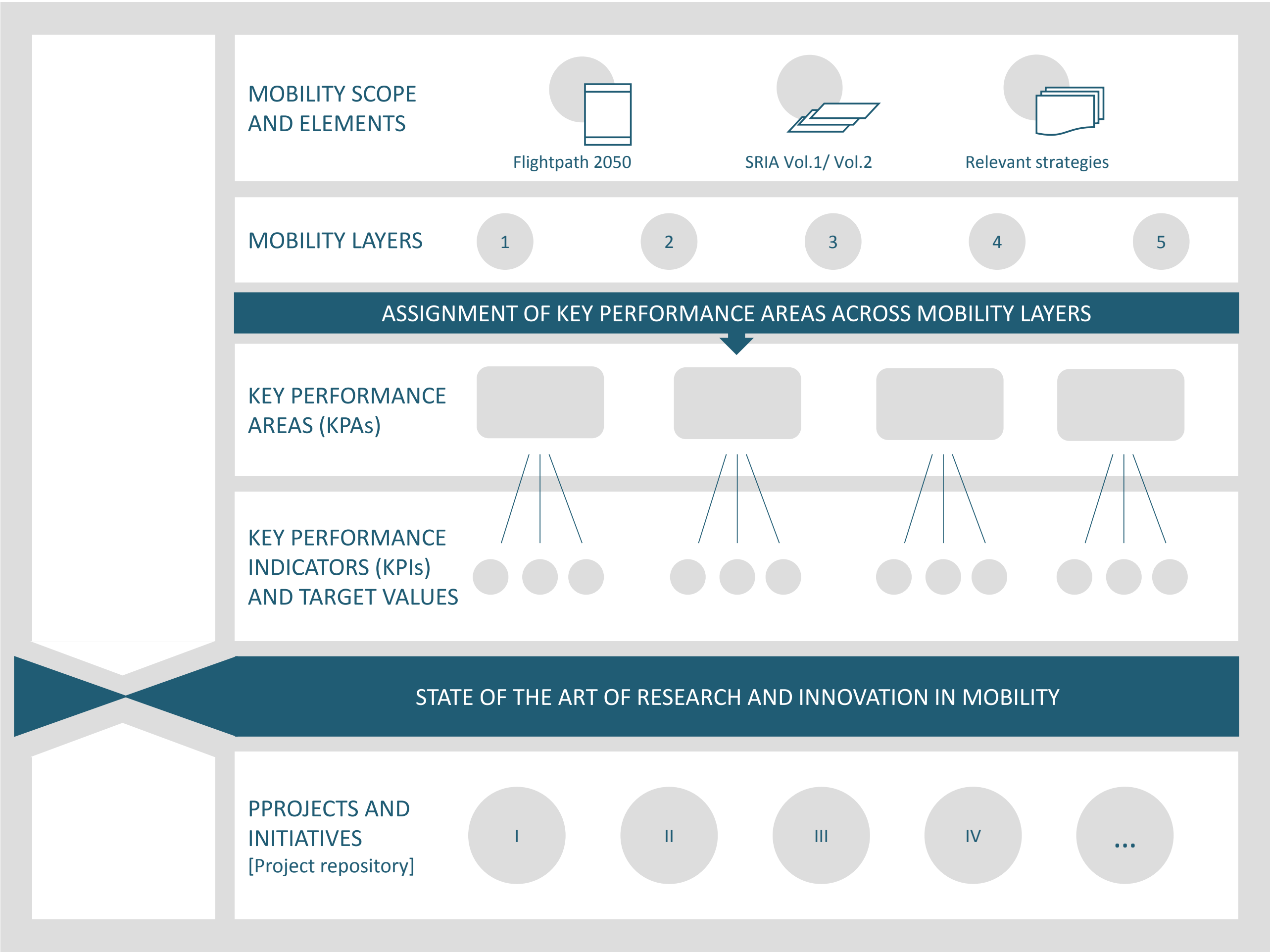

Figure 1: CAMERA performance framework and related elements

1) In the first step, the mobility scope and elements are defined. This includes an analysis of the strategic agendas of many transport modes and the goals stated in them. An example from the aviation sector is Flightpath 2050 and the Strategic Research and Innovation Agenda, with the latter detailing the work required for reaching the goals defined in the former. The focus of CAMERA is

not restricted to the aviation sector, and includes other modes to obtain a comprehensive picture of the overall European transport sector.

2) Following this, five different mobility layers that are intended to capture the different aspects of mobility are identified. This includes how passengers perceive present and future mobility systems, the way the mobility system responds to requirements, and how users and providers react to disruptions in the system, or what kind of and how much mobility will be supplied in the future. A particular focus will also be placed on the air traffic management system since aviation is a major part of CAMERA.
3) Across these five layers different key performance areas (KPA) are defined to allow the performance of the mobility system to be examined from different perspectives. The same KPA can apply to different mobility layers. Some new areas in addition to the KPAs defined by ICAO are included in the CAMERA performance framework.
4) In a fourth step, a set of key performance indicators (KPIs) within each mobility layer is defined for the different KPAs. These indicators are the core of the performance framework since they enable the measurement of progress towards European mobility goals. Indicators are generally formulated in way that allows a quantitative assessment using available data by comparing the current value of a KPI against the target value, thus providing insight into further research and development needs. However, not all indicators are suited for a quantitative analysis, a range of KPIs of a more qualitative nature are also included to obtain a broader insight. Furthermore, the set of KPIs included in the performance framework in this deliverable is not exhaustive and there is scope to include additional ones in the further course of the project.

1.2 Mobility scope and elements

The analysis of the different European mobility strategies outlined in Table 1 shows that each transport sector places increasing importance on the intermodal alignment between different stakeholders. Therefore, within CAMERA the focus is not solely placed on the aviation sector but also considers the mobility goals established in other transport sectors. Below, the various strategic agendas as well as visions of the multiple transport sectors are outlined, a more detailed insight into these can be found in Annex A1. These strategies and respective goals build the basis for the definition of the key performance indicators. For each of these indicators the relevant strategies are therefore highlighted in the subsequent sections.

Table 1: Elements of the mobility strategy

Sector	No.	Elements of the mobility strategy	Reference documents
Aviation	1	European Commission (2011a), Flightpath 2050 - Europe's Vision for Aviation, Report of the High Level Group on Aviation Research, Directorate-General for Research and Innovation and Directorate General for Mobility and Transport.	https://ec.europa.eu/transport/sites/transport/files/modes/air/doc/flightpath2050.pdf
	2	Advisory Council for Aviation Research and Innovation in Europe (2017), Strategic Research and Innovation Agenda (SRIA) - 2017 Update, Volume 1.	https://www.acare4europe.org/sites/acare4europe.org/files/attachment/acare-strategic-research-innovation-volume-1-v2.7-interactive-fin_0.pdf
Rail	3	The European Rail Research Advisory Council (ERRAC) (2017), Rail 2050 Vision, Rail - The Backbone of Europe's Mobility.	http://www.errac.org/wp-content/uploads/2018/01/122017_ERRAC-RAIL-2050.pdf
	4	The European Rail Research Advisory Council (ERRAC) (2014), Strategic Rail Research and Innovation Agenda.	http://www.errac.org/wp-content/uploads/2014/11/CER_FosterRailReport.pdf
	5	European Commission (2015), Shift2Rail Joint Undertaking - Shift2Rail Masterplan.	https://ec.europa.eu/transport/sites/transport/files/modes/rail/doc/2015-03-31-decisionn4-2015-adoption-s2r-masterplan.pdf
	6	Goulding, L. and M. Morrell (2015), Future of Rail 2050, Arup.	https://www.arup.com/perspectives/publications/research/section/future-of-rail-2050
Road	7	European Road Transport Research Advisory Council (ERTRAC) (2018), Strategic Research Agenda (SRA) - Input to the 9th EU Framework Programme.	https://www.ertrac.org/uploads/documentsearch/id52/ERTRAC-Strategic-Research-Agenda-SRA-2018.pdf
Maritime	8	WATERBORNE TP (2011), Strategic Research Agenda - Overview, Issue II, May 2011.	http://www.waterborne.eu/media/1011/wsra_2011.pdf
All	9	Mobility4EU (2018), The Mobility4EU Action Plan.	https://www.mobility4eu.eu/project/action_plan/
	10	European Commission (2011b), Roadmap to a Single European Transport Area - Towards a Competitive and Resource Efficient Transport System.	https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN
	11	European Commission (2017), Strategic Transport Research and Innovation Agenda (STRIA).	https://ec.europa.eu/jrc/en/publication/brochures-leaflets/strategic-transport-research-and-innovation-agenda-stria-roadmap-factsheets
	12	Alliance for Logistics Innovation through Collaboration in Europe (ALICE), Research and Innovation Roadmaps.	http://www.etp-logistics.eu/
	13	European Mobility for the Future: Strategic Roadmaps and Performance Assessment, joint workshop between EU projects CAMERA and Mobility4EU	http://www.optics-project.eu/wp-content/uploads/2018/07/workshop-results_final.pdf
	14	Van Audenhove, F.-J., Dauby, L., Korniichuk, O. and J. Pourbaix (2014), The Future of Urban Mobility 2.0 - Imperatives to shape extended mobility ecosystems of tomorrow, Arthur D Little Future Lap in collaboration with UITP.	http://www.uitp.org/sites/default/files/members/140124%20Arthur%20D.%20Little%20%26%20UITP_Future%20of%20Urban%20Mobility%202%200_Full%20study.pdf
	15	European Technology Platform on Smart Systems Integration (EPoSS) (2017), Strategic Research Agenda.	https://www.smart-systems-integration.org/system/files/document/2017%20EPoSS%20SRA_0.pdf
	16	European Commission (2007), Towards a New Culture for Urban Mobility, Green Paper.	https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52007SC1209&from=EN
	17	European Cyclists' Federation (2017), Recommendations for Delivering Growth and an Effective Mobility System in 2030.	https://ecf.com/sites/ecf.com/files/EUCS_full_doc_small_file.pdf

1.3 Mobility layers

Five different mobility layers are defined, taking into account the strategic goals of the European (air) transport system such as Flightpath 2050 and the respective Strategic Research and Innovation Agenda (SRIA) (see Table 2).

Table 2: Mobility layers in CAMERA performance framework

Layer number	Layer name	Description
1	Mobility customer demand	This layer incorporates the customer perspective as well as the business focus. It includes the definition of customer profiles and their respective expectations, including passenger experience aspects. These have an impact on mobility choices and in the end on the demand for mobility. Another important aspect within this layer is the socio-political acceptance of mobility such as the impact of transport projects, for example. The business aspect addresses the incentives for innovation in new technologies, products, and services, and hence the potential for market penetration.
2	Mobility performance	This layer focuses on the performance of the mobility system itself. It will use and develop several key performance indicators related to the door-to-door journey, including economic and environmental considerations. These metrics will be valuable for travel process management - monitoring and forecasting the flows within the system. They will serve also as benchmarks for evaluating the impact of new technologies and services.
3	Resilience and re-configuration in mobility	This layer examines the re-configuration aspects of the mobility system - how it recovers and what the effects (perturbations) are from unexpected and undesirable circumstances (disturbances) such as, for instance: bad weather, an external malign attack, a crisis, an ATC strike, or simply a bottleneck in a transport process. This air transport resilience/robustness uses a number of metrics that measure how delay is propagated through the system if there is a disruption. Is the system able to cope with the situation? How quickly? What is the stress? What is the impact? This layer also covers trip reconfiguration in terms of passenger management, information management, and potential transfer between transport modes in the case of major disturbances.
4	ATM system properties and performance	The air traffic management (ATM) system may be improved within required safety bounds through advances in both its technical and operational aspects. Europe's ATM is integral to the Single European Sky (SES) and is undertaken inside a performance framework whose second reporting period (RP2) runs from 2015 to 2019. The European Union's Performance Review Body (PRB) has defined a selection of key performance indicators (KPIs) which serve as basis for analysing the ATM system's performance in RP2. These all concern areas that directly or indirectly affect the availability, duration, cost, and thus mobility choices of a passenger's journey. This layer will use these RP2 KPIs, where relevant, to study the mobility performance criteria of the ATM system, and will develop new KPIs if required. One aspect not currently covered by RP2 is the accessibility of the airspace to other vehicles, e.g. unmanned aircraft, which present a great challenge to ATM. KPIs will be developed to enable this integration to be monitored and reported upon.
5	Mobility supply side	This layer addresses the efficient provision of air transport interface nodes, including the right quantity of them, and standards, which are crucial for ensuring progress e.g. towards the accommodation of 25 million flights per year. It focuses on the optimisation of services and processes within these nodes and on the integration of air transport infrastructure with other modes. The goal is to achieve an intermodal network and related processes. This also includes the capability of integrating new (air) mobility concepts and technologies.

1.4 Key performance areas and key performance indicators

The second step regarding the establishment of the performance framework is the definition of key performance areas (KPA). These KPAs are then assigned to the five mobility layers with a KPA being potentially represented within multiple mobility layers. The next step then comprises the definition of several key performance indicators (KPI) for each KPA within each given mobility layer.

The Collins English Dictionary (2017) defines "performance indicators" (PI) 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".

Table 3: Definitions (ICAO, 2009)

Abbreviation	Terminology	ICAO definition
KPA	Key performance area	A method of categorising performance subjects related to high-level ambitions and expectations. ICAO has defined 11 KPAs[1]
(K)PI	(Key) Performance indicator	Current/past/expected performance is quantitatively expressed by means of an indicator
PF	Performance framework	A set of definitions and terminology describing the building blocks used by [...] community members to collaborate on performance management activities

ICAO (2009) has established a number of useful definitions with regard to performance assessment, as summarised in Table 3. Since indicators support objectives, they should be defined as progress towards a specific performance objective in mind. Indicators are not often directly measured; they are calculated from supporting metrics according to clearly defined formulas. It is to be noted that ICAO does not differentiate here between a PI and a KPI. In many contexts, however, including SESAR (e.g. see SESAR (2017)), a KPI is defined as having an associated target. In line with the overall CAMERA objectives and the performance framework developed in this deliverable, KPIs are defined for each mobility layer to quantify the level of achievement of the different goals: for each KPI, a target value is defined that represents the state or quantitative value to be achieved in the future. By measuring the KPIs across the research landscape the difference between the current and target values can be identified. This common set of indicators helps to identify those areas where research and innovation is lagging behind set targets.

The performance framework also includes desirable KPIs, which might not be so easy to measure but are still important aspects, such as environment-friendliness. Where possible, a KPI has an assigned target value that is in accordance with the long-term vision of the European transport system. These KPIs may be subject to further refinements in the course of the CAMERA project (for example, due to their measurability or to specificities of software modelling).

Many of the key performance indicators mention the passenger journey when defining goals for the future European transport system. In this deliverable, a passenger journey is defined as a trip from door to door, e.g. the starting point can be the passenger's home or work and the final destination can be the location of a work-related meeting or a holiday destination. Since CAMERA focuses on the integration of air transport with other modes, air travel is considered as an essential part of the passenger journey. This type of journey is split into five different steps (Figure 2). The first part - door-to-kerb (D2K) - denotes the access to the

[1] 1, access and equity; 2, capacity; 3, cost effectiveness; 4, efficiency; 5, environment; 6, flexibility; 7, global interoperability; 8, participation; 9, predictability; 10, safety; 11, security.

airport, which can be conducted by using different transport modes and routes. The second part - kerb-to-gate (K2G) - covers the journey segment within the airport, from arrival at the airport up to the departure gate. The third segment - gate-to-gate (G2G) - includes boarding and disembarking as well as the actual flying time, and includes all connections. Stages four and five of the passenger journey mirror the access to the airport and the processes within the terminal and are thus denoted gate-to-kerb (G2K) and kerb-to-door (K2D).

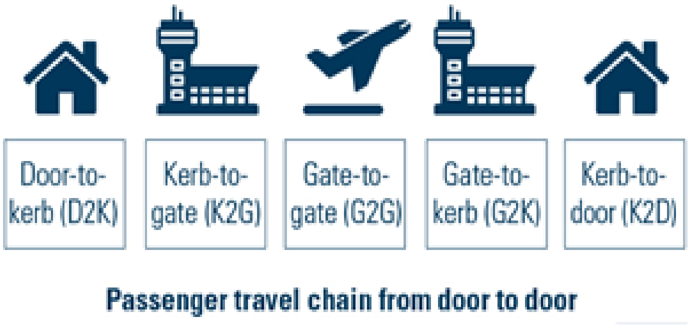

Figure 2: Different steps of passenger journey (source: DATASET2050)

In addition to this, a passenger journey can also take part in a single urban region, without incorporating an air-travel segment connecting two different urban regions, for example. An urban journey may also incorporate several steps since passengers have to switch between transport modes in order to get from their starting point to their destination. Differentiating between an urban journey and a journey that incorporates air travel, i.e. a long-distance journey, is accounted for in the deliverable by considering two different passenger classes - urban and long-distance passengers. The key performance indicators that apply directly to passengers are therefore ranked according to their importance for these two classes. More detail will be provided in the following sections.

1.5 Structure of the deliverable

Based on this approach, CAMERA deliverable D2.1 is structured into four main parts which all contribute to the establishment of the performance framework.

1) The first part (Section 2) focuses on the development of customer profiles. Since there is a large variety of passenger expectations and needs, these are clustered into different groups to differentiate between them in the performance framework (where possible).
2) The second part of the deliverable focuses on the derivation of key performance indicators for each KPA in each pre-defined layer (Sections 3.1 to 3.5), and target values for the individual KPIs. For the KPIs that apply directly to passengers a rating is introduced that shows their importance to the different passenger groups defined in the first part.
3) The third part of the deliverable (Section 4) describes the performance framework and the elements that provide the input for subsequent analysis within this project.
4) Based on the analysis conducted within the layers, an initial indication to potential gaps and bottlenecks is given in part four (Section 5). This part also concludes the deliverable and elaborates on the next steps.

2 Definition of customer profiles

2.1 Introduction

The different mobility strategies and their respective goals highlighted in Section 1 and in Annex A1 emphasise the customer-orientated approach to designing the future European transport system, thus reflecting passengers' expectations of and requirements for this transport system and overall mobility. The strategies are also concerned with the acceptance of the transport system within the broader social context. Moreover, the business aspect, addressing the incentives for innovation in new technologies, products and services and hence the potential for market penetration in Europe, has to be incorporated. Following this reasoning, this section elaborates on passenger expectations and derives relevant customer profiles and their expectations. These profiles are applied in the further analysis when assessing the importance of various goals for these distinct user groups.

In the CAMERA project, users are defined as passengers (humans) using mobility products and services, and are therefore not cargo, freight or corporations. Passenger requirements vary according to travel context or travel motivation (business, leisure, both=bleisure), range (long haul vs. short haul), and travel experience (frequent flyer vs. sporadic flyer). Trying to capture this nuance, two types of passenger profiles are developed: the urban-transport passenger and the long-distance-transport passenger, where long-distance travel includes at least one air trip in the travel chain. As the CAMERA project is especially concerned with future needs of passengers, the focus is on developing future customer profiles. Passenger profiles, characteristics and expectations for the transport system are topics of interest for many stakeholders such as mobility providers, researchers and industry organisations. However, it is challenging to develop future passenger profiles as one can only assume how future generations might live and travel. To start off, a literature review has been conducted to find reports to include in the meta-analysis. Few reports have been published on future passenger profiles. These encompass different approaches and focuses[2]:

- The General German Automobile Club ADAC is one of the largest automobile clubs in the world. Among other topics, it works on the future of mobility and future mobile lifestyles. The Club has published different passenger types for 2040 such as the Public Traveller, the Lost-Cost Driver or the High-Frequency Commuter (ADAC, 2017). A short and quantitative description of the different passenger types is provided, but there are no details about the process of deriving these profiles, or data to back these up.
- Two AMADEUS Future Traveller Tribes reports provide information on key consumer groups travelling in 2020 and 2030. All profiles have a door-to-door (D2D) focus (including one air trip) and next to a quantitative description, personas are provided to gain a better understanding of the passenger profiles (Future Foundation (2015); Henley Centre HeadlightVision (2007)). Both reports are included in this analysis as well.
- The DATASET2050 project, a Coordination and Support Action funded by the EU, published six traveller profiles for the EU28 and EFTA-countries for 2035. All profiles are developed based on a meta-analysis of current passenger profiles and on demographic developments within Europe, such as the trend towards an ageing population or the increasing environmental awareness among a small part of European society. As within the AMADEUS reports, the focus in this deliverable is on door-to-door trips including an air trip. Examples are the Digital Native Business Traveller, the Family and Holiday Traveller or the Culture Seeker (Kluge et al., 2017).
- The consulting firm Capgemini conducted three workshops with selected experts from the Dutch travel industry and developed a vision for travel in 2025. In their final report, four personas are introduced as well, encompassing socio-demographic information and travel preferences

[2] Some of the reports for this analysis are also included in the DATASET2050 meta-analysis

(Capgemini, 2015). Compared with the other passenger segments from the studies mentioned above, the profiles from Capgemini have a more local and national focus and offer a suitable addition to this analysis.

- Cognizant published a report on the future of air travel and eight disruptive waves of change within the mobility industry, including three emerging, next generation customer segments for 2025: global citizens, customers from new regions and demographics and sustainability minded travellers (Cognizant, 2017).

2.2 Developing future passenger profiles

Table 4: Passenger parameters used in this analysis (own depiction)

Parameter	Note
Journey segment focus	(1) door-to-door (D2D), (2) only air travel, (3) only urban travel / commuting
Main travel purpose	(1) private, (2) business, (3) missing (no information)
Frequency of travel	(1) seldom, (2) occasionally, (3) frequently, (4) very frequently
Age	Age or age range
Sex	(1) male, (2) female
Family status	No. of family members (e.g. no. of children)
Income	(1) low, (2) medium, (3) high
Size of household	1, 2, 3, 4, 5, >6
Booking/ information gathering	(1) online, (2) travel agency
Accommodation	(1) hotel, (2) hostel, (3) couchsurfing, (4) family/friends, (5) holiday flat, (6) other
Profession	Student, business, freelancer, etc.
Number of persons joining	(1) none - solo travel, (2) no. of people
Organisation of trip	(1) private, (2) outsourced
Education	(1) low, (2) medium, (3) high
Travel cost	(1) low, (2) medium, (3) high
Expected comfort level	(1) low, (2) medium, (3) premium
Airline and modes	Types of preferred transport mode
Technological affinity	(1) low, (2) medium, (3) high
Environmental awareness & other behaviour change	(1) yes, (2) other behaviour change
Trip research sources	TripAdvisor, peer reviews, travel blogs etc.
Use of social media	Name of platform/ social network
Degree of personalisation	(1) low, (2) medium, (3) high
Activities during travel and other notes	Working, entertainment, sleeping etc.

The six reports above incorporate a total of 32 future passenger profiles and have all been considered in this analysis. Firstly, passenger profiles (also known as passenger types or customer profiles) have been structured according to passenger parameters described in Table 4. Some information, such as age, is not always provided but it could be helpful to include these profiles in this analysis anyway. The age group has been estimated where necessary based on the life status and description of the passenger profile. For instance, students - vocational education, bachelor's degrees, master's degrees, and doctorates - are normally from 18 to 28 years old, based on the average entry age and graduation age of 26 European countries (OECD, 2017). Business commuters are estimated to be from 30 to 65, given that average the European population will retire at 65.4 years (European Commission, 2015). As some women have children at a later stage in their lives, for instance due to pursuing a university degree and gaining experience in the labour market first, family profiles are estimated to be from 30 to 50 years (OECD, 2011). Moreover, it is assumed that a person can start to travel alone at 15, however, most passengers will probably start travelling alone at 18 or older.

Moreover, as explained in Section 1, profiles and passenger expectations can vary, depending on the context. Hence, in the second step, existing passenger profiles have been grouped into two main travel segments: 1) Urban travel (e.g. day-to-day commuting) and 2) Long-distance travel (includes one air trip, e.g. business travel or holiday travel). Some profiles might be both urban traveller and long-distance traveller. In the next section, these passenger profiles are structured and used to develop new customer profiles.

2.3 Results

2.3.1 Urban transport passengers

In this report, urban passengers are defined as people commuting to work on a daily basis, visiting friends and relatives within the same area, going shopping or taking care of other day-to-day duties. They could also be tourists or visitors in a city or urban area. By contrast, long-distance passengers are not travelling for day-to-day purposes, but for visiting friends and relatives (also known as VFR tourism or VFR travel), going on holiday, or making a long-distance business trip. In the following, researched profiles from the literature review of both main travel segments are clustered according to travel purpose (private, business, both) and age group (see Figure 3, Figure 4, Figure 5 and Figure 6 below). Customer profiles sharing similar characteristics have been grouped together forming a new future passenger profile for the purposes of the CAMERA project. Table 5 and Table 6 below summarise the main characteristics and passenger expectations.

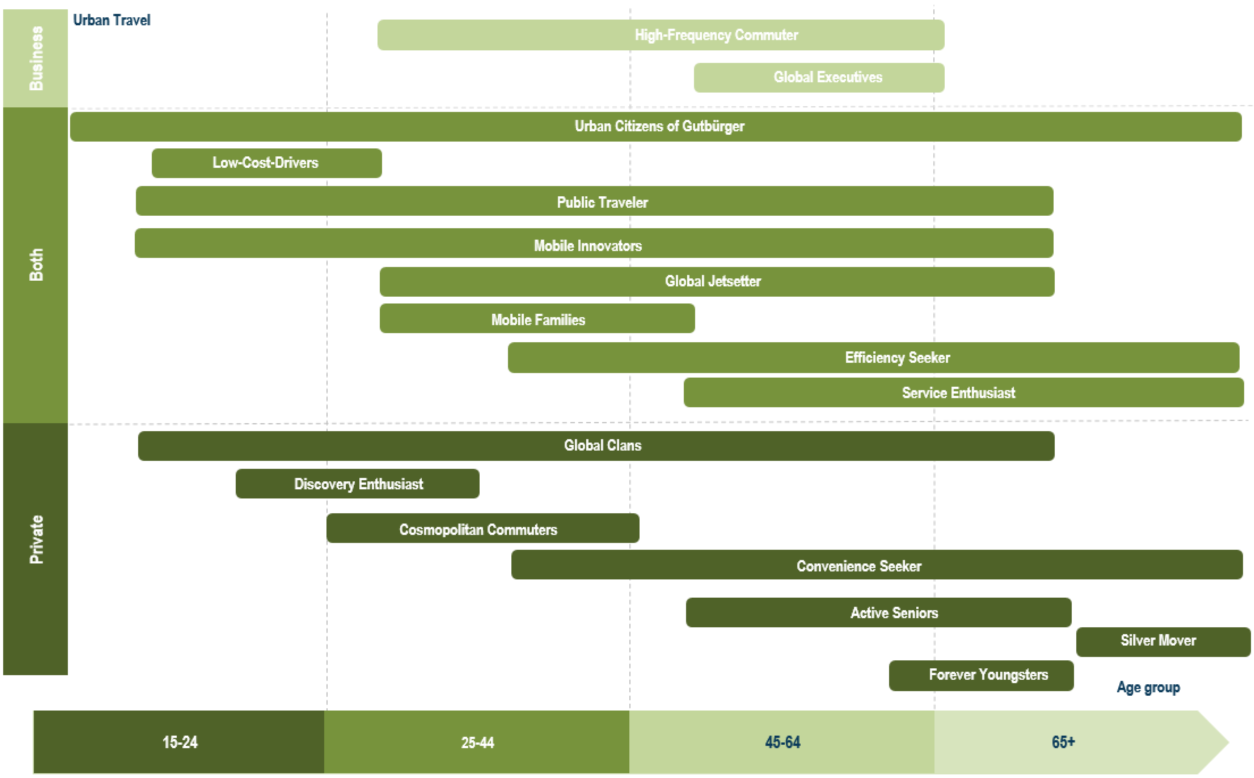

Figure 3: Urban traveller profiles according to age group and travel purpose (business, private, both)*

*(Gutbürger = socially responsible citizens)

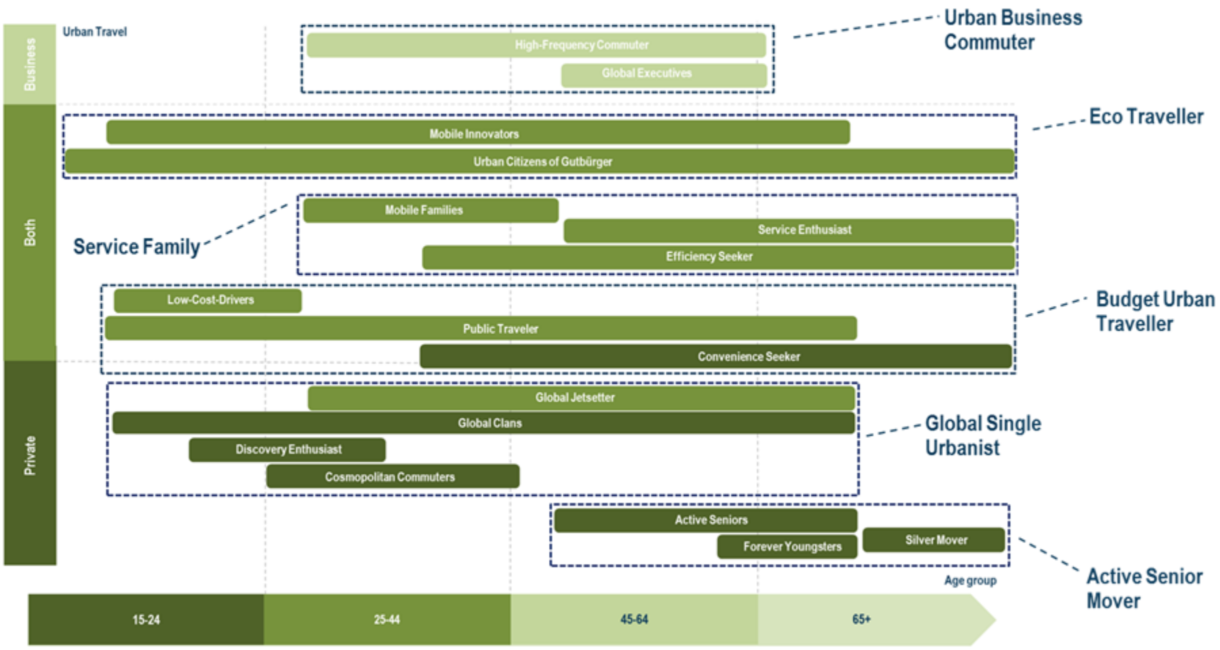

Figure 4: Newly developed future urban traveller profiles

Table 5: Overview of future urban passengers

Category	Active Senior Mover	Urban Business Commuter	Budget Urban Traveller	Eco Traveller	Service Family	Global Single Urbanist
Existing passenger profile from literature review	Active Seniors; Forever Youngsters; Silver Mover	High-Frequency Commuter; Global Executives	Low-Cost Drivers; Public Traveler; Convenience Seeker	Mobile Innovators; Socially responsible urban citizens ("Gutbürger")	Efficiency Seeker; Service Enthusiast, Mobile Families	Global Clans, Discovery Enthusiast, Cosmopolitan Commuters, Global Jetsetter
Main travel purpose	private	business	Mainly private	both	both	Mainly private
Predominant age group	50+	30-65	18 - 70	15[3] - 70	30+ (plus children)	18 - 70
Income level	low/medium	high	low	high	medium/ high	low / medium / high
Occupation	Mostly retired or end of working life	business/ executive; job-nomad (e.g. project based work)	student; looking for jobs, mini-job; low profile job	N/A	Business / solid Job in middle or upper Management (both parents might work)	Knowledge worker, business
Household size	1 to 2	N/A[4]	1 to 2	N/A	3 - 5	1
Travel party size	1 to 2	N/A	1 to 2	N/A	3 - 5	1 to 2
Frequency of travel	seldom	frequently/ very frequently	N/A	N/A	frequently	seldom / very frequently
Expected level of comfort	medium / premium	premium	low / medium / sometimes premium	N/A	medium / high	low / medium / high
Degree of personalisation	high	medium / high	low/high	high	medium / high	high
Booking/Information gathering	N/A	online	online	online	online	online
Technological affinity	N/A	high	high	high	medium	high

1) Active Senior Mover

This senior urban passenger type is 50 or older and usually travels for private reasons, either alone or accompanied by one fellow traveller. He or she is in the second half of their working life or, if older, already retired. Their income level is low to medium. "Being active" and "personal health" are important for this customer group. Due to their advanced age, these passengers might have limited personal mobility and hence they are in need of a safe and age-appropriate transport system. They also expect a medium to high level of comfort and a high degree of personalisation when travelling. Creating a more age-appropriate transport system can open up new business opportunities.

2) Urban Business Commuter

The Urban Business Commuter travels very frequently to and from their workplace on a daily basis. He or she is aged between 30 and 65 and has a high level of income, indicating either an executive position or a more

[3] as explained above, it is assumed that a person can start to travel alone at 15, however, most passengers will probably start travelling alone at 18 or older.

[4] Missing (no information available)

project-based, freelancing profession. A high level of comfort, a medium to high level of personalisation and, due to a high technological affinity and working activities during travel, a stable on-board Wi-Fi connection is expected. Hence, transport projects that increase connectivity at stations and on-board transport modes might be very welcomed and accepted positively by the Urban Business Commuter.

3) Budget Urban Traveller

The Budget Urban Traveller lives in the suburbs or countryside, with a typical household party size of one or two, and travels mainly for private reasons. He or she is mainly between 18 and 70 years old and has rather low education and income levels. People belonging to this customer group might be students, mini-jobbers, low-profile jobbers, or job seekers. Travel is considered more as a hassle, especially due to the long commute into the city centre. They expect a low to medium level of comfort (sometimes premium). The expectations in terms of personalisation of journeys varies from low to high. Their technological affinity is high and booking and information gathering is mainly done online. Hence, comprehensive and real-time transport information should be provided online as well.

4) Eco Traveller

The Eco Traveller travels for both, private and business purposes. They are between 15 and 70 years old, with a high level of income, and they live in the cities or suburbs. This customer profile type is very much environment-minded and tries to travel in as eco-friendly a manner as possible. Like the Budget Urban Traveller, booking and information gathering is mainly done online, hence, travel information should be provided via this channel. The Eco Traveller is very innovative and open to new transport modes and mobility concepts as long as these are focused on the environmental aspects of mobility. Hence, the degree of personalisation of transport is high, but also the willingness to spend a large amount on travel costs. Such environmental aspects could set incentives for innovative mobility services and products in the industry, and also for government transport and infrastructure projects.

5) Service Family

This profile does not refer to one person but to a whole family. The predominant age of the parents, who are most probably married, is 30 or older (with children under 15). Family members are rather highly educated, with both parents having a solid job and a medium to high income. However, money and time are still scarce resources and travel is mostly seen as a hassle. Depending on the context, they spend a small to large amount on transport. The Service Family wants to be in control of its travel activities and is in need to family-friendliness and the principal function of mobility - to get from A to B.

6) Global Single Urbanist

The Global Single Urbanist is between 18 and 70 years old and mainly travels for private reasons. The education level of this profile is rather high and their income level can vary from low-medium to high. He or she might be in a romantic relationship, but lives alone. Hence, the travel party size is one or two people. He or she does not want to spend much on transport but has high expectations, such as a high degree of personalisation and the availability of all modes of transport (train, taxi, car sharing, etc.). Travel information is retrieved online, from travel blogs or from peers. This profile type enjoys travelling, always looking for inspiration, an authentic experience, making new friends and achieving personal development. Hence, mobility should also be an adventure in itself and not just fulfil the transport function of going from A to B.

2.3.2 Long-distance passengers

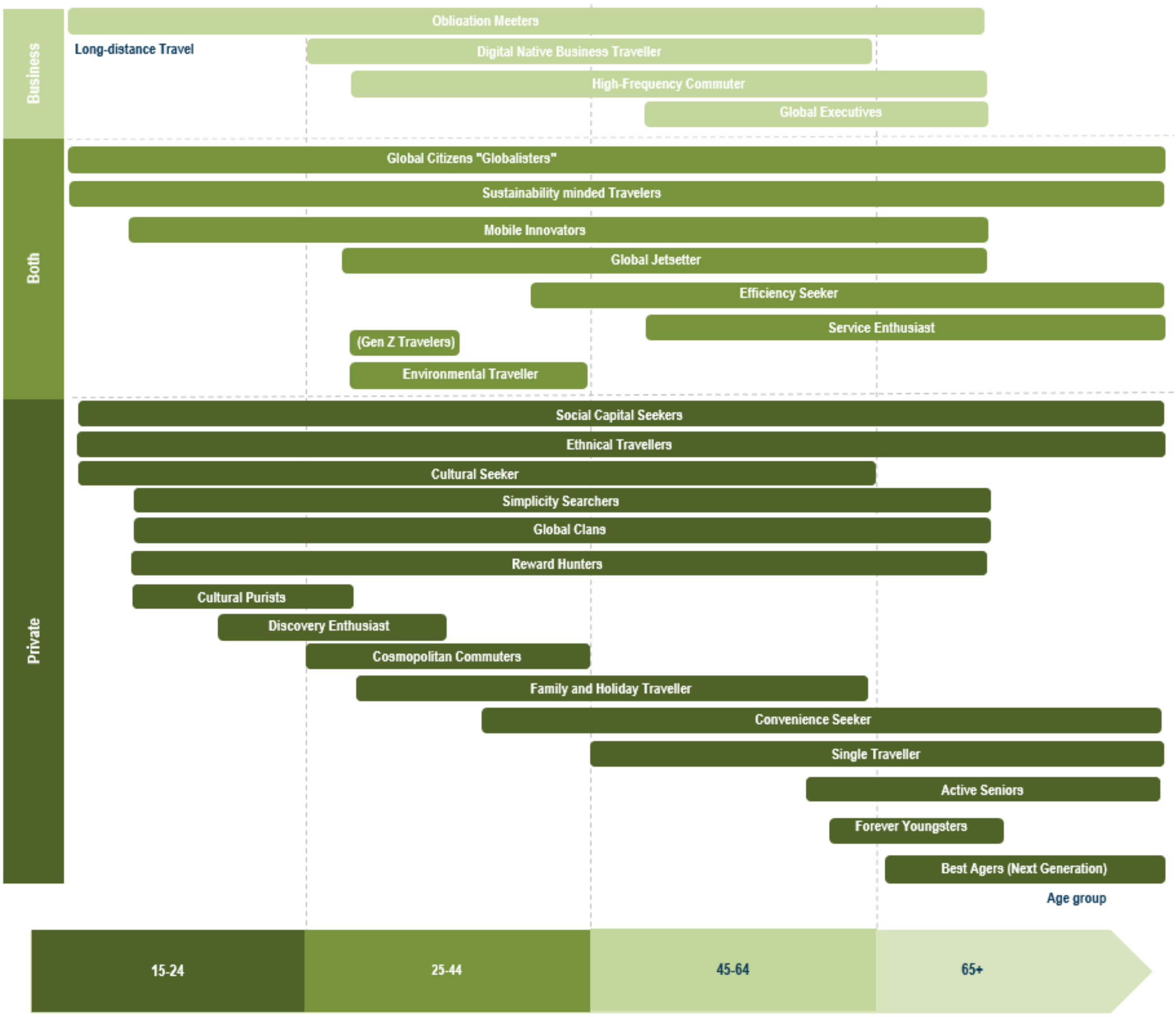

Figure 5: Long-distance traveller profiles according to age group and travel purpose (business, private, both)

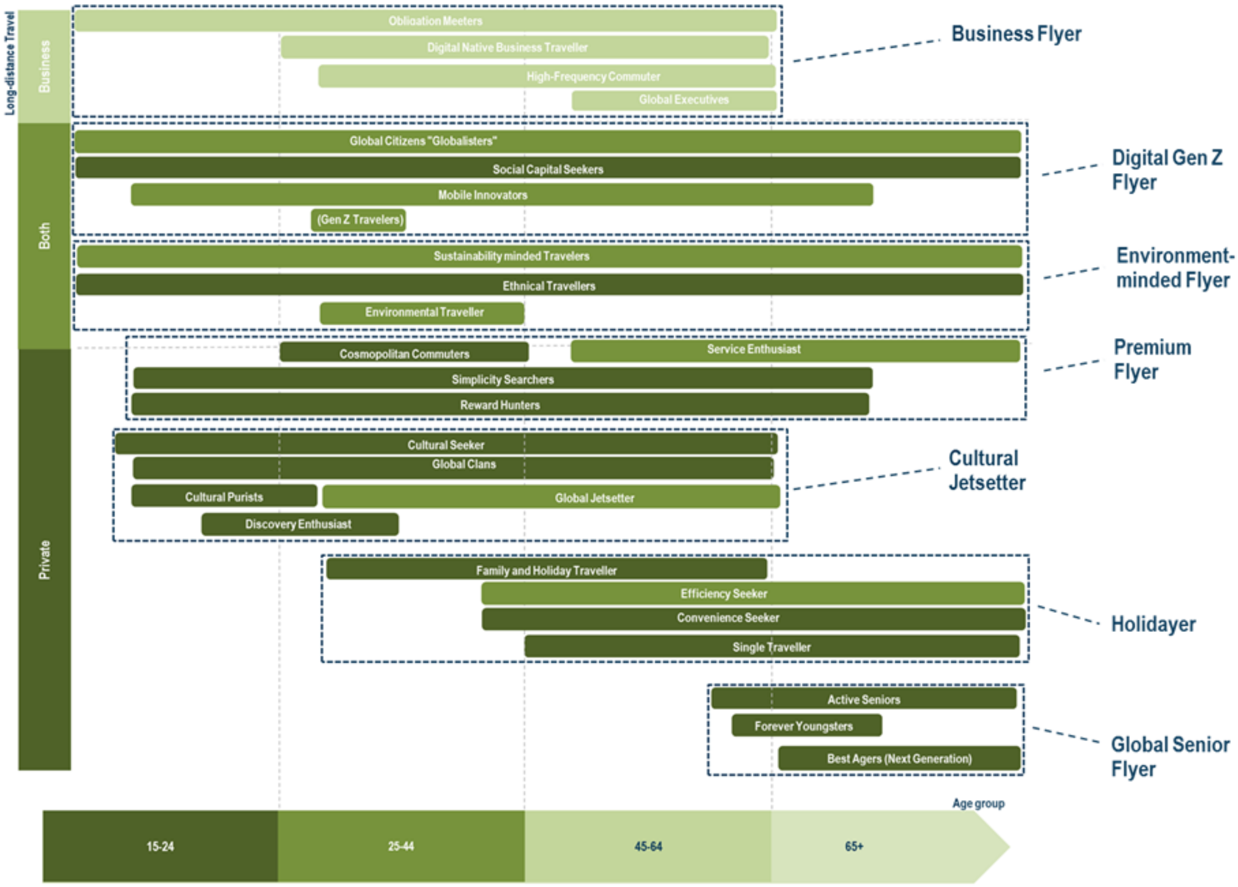

Figure 6: Newly developed future long-distance traveller profiles

Table 6: Overview of future long-distance travellers

Category	Business Flyer	Digital Gen Z Flyer	Environment-minded Flyer	Premium Flyer	Cultural Jetsetter	Holidayer	Golden Senior Flyer
Existing passenger profile from literature review	Obligation Meeters; Digital Native Business Traveller; High-Frequency Commuter; Global Executives	Global Citizens "Globalisters"; Social Capital Seekers; Mobile Innovators; Customers from new regions and demographics (Gen Z travellers)	Sustainability-minded Travellers; Ethical Travellers; Environmental Traveller	Cosmopolitan commuters; Service Enthusiast; Simplicity searchers; Reward hunters	Cultural Seeker; Global Clans; Cultural purists; Global Jetsetter; Discovery Enthusiast	Family and Holiday Traveller; Efficiency Seeker; Convenience Seeker; Single Traveller	Active Seniors; Forever Youngsters; Best Ager (Next Generation)
Main travel purpose	business	Mainly private	private & business	Mainly private	Mainly private	Mainly private	private
Predominant age group	18 - 65	15 - 70	15+	18+	15 - 65	30+ (with children under 15)	50+
Income level	medium / high	high	medium	high	low / medium / high (more medium / high)	low / medium / high	medium
Occupation	Business or job-nomad (project work)	N/A	business	business	Student, business, knowledge worker	from low profile job to business	mostly retired
Household size	N/A	N/A	N/A	from solo-traveller up to 5 persons (family size)	1 or more	from solo-traveller up to 5 persons (family size)	1 to 2
Travel party size	1 to 2	N/A	1 to 2	up to 5 persons (family size)	1 to 2	single and up to 5 persons (family size)	N/A
Frequency of travel	frequently / very frequently	N/A	N/A	occasionally to very frequently	occasionally to very frequently	N/A	frequently
Expected level of comfort	medium / high	N/A	low	medium to high (premium)	low to high	medium / high	medium
Degree of personalisation	medium / high	high	high	high	low to high (more high)	medium / high	high
Booking/ Information gathering	online	online	N/A	in-person, travel agency	online and travel agency	online	N/A
Technological affinity	high	high	low / medium	N/A	high	medium	medium

1) Business Flyer

This customer profile refers to the classical corporate traveller who travels for business purposes. While is it assumed that most Business Flyer are between 30 and 65, this passenger type can be quite young (down to

18 years old) in special cases, such as young entrepreneurs, trainees or apprentices. Business Flyers travel frequently or very frequently for projects, meetings, conferences, exhibitions, or to attend incentive trips. The travel party size is typically one to two people and the income level is medium to high. Travel time is mainly used to get work done, hence a good Wi-Fi-connection, power connections and a medium to high level of comfort within the transport modes and at stations is important for the Business Flyer. Booking and information gathering is mainly done online, and depending on seniority could also be through an assistant.

2) Digital Gen Z Flyer

The Digital Gen Z Flyer travels mainly for private purposes, has a high income level, and a wide age range between 15 and 70. He or she is very digitally connected and might be very active on social media platforms. In terms of travel, the Digital Gen Z Flyer depends on user-generated content and personal recommendations. Travel is a life experience shaping their identity, providing a time to learn, socialise and discover. He or she is very innovative and open to new modes and mobility concepts. Hence, this customer profile could be a potential user of innovative, digital travel and recommendation platforms, for instance.

3) Environment-minded Flyer

Like the Eco Traveller from the urban customer profiles, the Environment-minded Flyer is characterised by a high environmental awareness and the attempt to live and travel in an environmentally conscious way. He or she can be 15 or older, travelling for either private and business reasons (alone or accompanied by one person). While their income level is medium, travel costs can be low to high, depending on the eco-friendliness of the mode. As sustainability is the main priority, their expected level of comfort is low. Their technological affinity is low to medium.

4) Premium Flyer

The Premium Flyer travels mainly for private reasons, is 18+ years old and has a high-income level. He or she can travel alone or with up to five people, can be single or married with a family. Travel activity can vary from occasionally to very frequently. The journey itself is high-end: relaxing at the beach, wellness-driven, or spectacular (e.g. flying in a helicopter to concert). He or she wants a full-service packages, friendly staff, and a high degree of personalisation. They can therefore spend a very large amount of money on mobility. Premium modes are chosen, such as Teslas or taxis. Booking is done in-person or using a travel agency. This customer profile might offer incentives for new mobility innovations around high-end and premium transport.

5) Cultural Jetsetter

The Cultural Jetsetter is focused on intellect and culture, travelling mainly for private reasons. He or she can be from 15 to 65 years old and quite highly educated. Income levels can vary from low-medium to high, depending on the profession, and a low to medium amount is spent on travel. The travel party size is one or two people and the frequency of travel can vary from occasionally to very frequently. In addition, the expectations regarding comfort and personalisation can also vary (e.g. they might also stay in hostels or do couchsurfing). Booking and information gathering is done online, via a travel agency, ‘word-of-mouth’, via travel blogs, or from peers.

6) Holidayer

As with the Service Family, Holidayers travel mainly for private reasons and their group profile can be a family or a single person. The predominant age is 30 or older (with children under 15 in the case of a group profile). Their income level varies from low to high. A low to medium amount of money is spent on travel costs. Travel itself is perceived as a hassle. This profile wants to relax on vacation and to avoid any stress, so the trip will be pre-organised and pre-booked. Typical sources for trip research, besides the Internet, are experts and peer reviews. Holidayers expect a medium to high level of comfort and personalisation.

7) Golden Senior Flyer

Golden Senior Flyers are 50+ years old and travel frequently for private purposes. Their income level is medium and they are mostly retired or within their last years of their working life. The household of Golden Senior Flyers comprises one or two people. Golden Senior Flyers spend a medium amount of their income on travel. They expect a medium level of comfort and a high degree of personalisation. Although their age might suggest otherwise, they have a medium affinity towards technology. Simplification, health and activity are important to them. As seen in the section on the Active Senior Mover, creating a more age-appropriate transport system for this profile can open up new business opportunities. Moreover, mobility should be simple and easy to use for these passengers, such as via an easy app, single-ticketing, or personal assistance

Each key performance indicator in the following five layers is assigned, where applicable, to one or both of the customer profile types. Urban passengers do not travel for as long or as far as the long-distance passengers, therefore their needs and preferences might be slightly different. The importance of the KPIs is ranked according to low, medium and high, indicating the emphasis a passenger group may place on achieving this particular KPI.

Not all KPIs in the framework may apply to passengers directly. The KPIs mostly affect mobility suppliers and thus passengers indirectly. These types of KPI are not assigned to either of the passenger groups.

3 Mobility layers

3.1 Mobility customer demand (Layer 1)

3.1.1 Introduction

This section presents the KPAs and their KPIs for Layer 1. The development of these is based on several sources. Besides those already mentioned in Section 1 of this deliverable (workshops, strategic papers & desktop research), 17 semi-structured expert interviews have been conducted with European transport providers and mobility experts to provide further input on this topic and to incorporate the industry's point of view. The overall purpose of the interviews was to gain expert and industry knowledge of:

1) Characteristics of current and future mobility passengers;
2) Insights into methods used to collect and analyse the mobility market, and
3) The future of mobility - how we will to travel in the future, the challenges, modes of the future, and need for further action or investments.

To get a broad view of these areas, and to cover the entire transport system, providers from along the whole travel chain - public transport providers (access and egress modes in the case of long-distance travel), airlines, airports, and suppliers from the B2B sector - were interviewed. A detailed list of the interview sample can be found in the Annex A2.

The final list of KPAs and KPIs for mobility customers are presented below. These do not apply to a specific transport mode or journey segment but to the overall European transport system. KPAs can not be seen as completely isolated since boundaries are blurred and definitions are interrelated. For instance, single ticketing belongs to the Mobility as a Service (MaaS) KPA but is also part of Intermodal Integration. Moreover, other key words such as safety might occur in other layers of the performance framework as well, however in this context everything is passenger-orientated.

3.1.2 Key performance areas

In this context of user needs, the **Interoperability** and **Flexibility** KPAs mainly focus on aspects that are related to the concept of Mobility as a Service (MaaS). MaaS focuses on passengers, adapting mobility products and solutions towards the personal preferences of users (individualisation). MaaS incorporates the possibility of using different modes for a given route according to the personal situation (flexibility, spontaneity, on-demand), and offering information and travel packages from a single source (one-source: single platform and single ticketing). Passengers' personal travel devices, such as smartphones or smartwatches, are considered to be a travel partner, helping to make the journey as pleasant and efficient as possible. The travel partner must, however, be reliable in terms of travel time and real-time travel information (reliability, punctuality). Travel processes should be user-friendly (simple processes; easy to use).

The **Interoperability** KPA addresses intermodal integration and concerns reducing the overall booking time through single ticketing options (intermodality), reduced waiting time and easy and fast travel (seamlessness and integration). An intermodal insurance should be available for travel cancellation, lost bags etc. across all modes (insurance). Consistent quality must be ensured at all touchpoints. All of this is enabled through data sharing between mobility providers and different modes.

The second KPA is concerned with the **Digitalisation and Information** of mobility (pre, during, and post journey). Providing real time and high quality travel information, such as on the live status of luggage or current traffic situation, helps to 'free the mind' of passengers. If something goes wrong along the journey, (pre-travel) support and real-time information is actively provided, accessible for all passenger types through online and offline channels in an understandable, multi-lingual way (monitored journey and comprehensibility). Digitalisation also allows exciting content to be created while travelling, allowing travel time to be used for work or entertainment (enhanced use of travel time).

Passengers are humans and differ in all sort of ways. The third KPA **Access and equity** addresses issues related to society and social inclusion and is thus concerned with the inclusion of all passenger types, e.g. taking into consideration specific needs when travelling with children (comfort), reduced mobility of elderly people (accessibility), the different travel budgets people might have (affordability), or language barriers (borderless travel). Human assistance and the interpersonal contact available for passengers will remain essential (human touch). Moreover, this KPA refers to benefits for society overall. Social benefits of mobility could be sustainable business models (eco-friendliness) or a high seat-load factor, transporting as many people as efficiently as possible. Generally, mobility in Europe should be fair and transparent for both users and providers (transport justice), and socially compatible. Passenger requirements should be brought into line with a plausible business case (i.e. coverage of rural areas, easy reassignment of tickets, or aircraft sharing).

Externalities from the overall mobility system should be internalised. This often relates to the **Environment** KPA, implying that a higher importance will be placed on reducing greenhouse gas emissions in the transport sectors, as well as incentivising users and providers to convert to environmentally friendly technologies and solutions.

Safety and **Security** are the top priority in the overall transport system, not just in terms of safe travel but also in terms of open data and personal data security. The passenger should decide which personal data to give to the mobility provider (e.g. only filtered for one journey or for overall use of the mode). There is a need for more transparency about what happens with the data and where and when it is stored.

3.1.3 Key performance indicators

Table 7: Key performance indicators Layer 1

KPA	KPI	Target value	Urban passenger	Long-distance passenger	References[5]
Interoperability	Availability of options for flex ticketing & single ticketing (e.g. rail & fly): Number of tickets required for all journey segments	1	low	high	13, Paul and Kluge (2017), Expert interviews
Flexibility	Options and availability for transport on demand: Percentage of travel segments offering transport on demand	≥90%	medium	high	3, 4, 5, 7, 13, Paul and Kluge (2017), Expert interviews
Digitalisation and information	Availability of on-board content and entertainment: Percentage of total journey time where on-board entertainment/content is offered	≥80%	low	high	13, Expert interviews
	Availability of (free) Wi-Fi connection on-board and during all phases of the journey: Percentage of travel segments offering free Wi-Fi	100%	medium	high	7, Paul and Kluge (2017)
	Average passenger satisfaction rating on a standard, 5-point Likert scale (with neutral mid-point)	4.5	medium	high	IATA (2018), Skytrax (2018)
Access and equity	Share of availability of personal assistance services during all journey segments	≥90%	high	high	Paul and Kluge (2017), Expert interviews
	Number of different fare schemes available for different user groups	Minimum of 6 ticket options budget, economy, premium, student discount, family/ group discount, retirement discount	high	high	13
	Load factor of each transport mode	N/A	medium	high	13, Paul and Kluge (2017)
Environment	CO_2 efficiency of transport ("environmental footprint"): equivalent CO_2 emissions (in terms of radiative forcing) per passenger per km.	Reduction of greenhouse gas emissions (GHG) by at least 60% compared to 1990 levels	high	high	6, 7, 13, Paul and Kluge (2017), European Commission (n/a)
Safety	Number of fatalities per 10^8 journeys (target level of safety)	Target levels of safety of different transport sectors	high	high	3, 7, 10, 13, European Union Agency for Railways (n/a), Tordai (2006), ICAO (2014)
	Level of passenger safety perception	"Perfectly safe"	high	high	3, 13
Security	Share of mobility providers applying common data protection rules	Enforcement level of Europe-wide data protection laws across mobility providers	medium	high	2, 3, 4, 5, 7 11, Expert interviews

[5] The numbers indicate the reference strategies outlined in Section 1 of the deliverable

3.2 Mobility performance (Layer 2)

3.2.1 Introduction

The mobility performance layer (Layer 2) is built to address the central issue of the performance of the transportation system as a whole. One of the main goals in terms of performance is set by Flightpath 2050, which explicitly sets a target of 90% of intra-Europe journeys involving an air leg being possible in under 4 hours door-to-door (D2D) by 2050. Many other issues can be linked to this central concept, some of them being necessary conditions for reaching the target. Accessibility, interoperability, and punctuality are some of these. Because this layer encompasses the air transport system, some of the performance indicators of Layer 4 (ATM) could, in principle, be included here. However, because we are focusing on a wider perspective by defining metrics that include all means of transport, or on their interface, most of the KPIs listed here are in fact independent of these specific means and could be used in other environments.

Note that this layer is very much supply-oriented. Whether or not the passengers actually want their door-to-door trip to take less than 4 hours, and under which conditions, are largely irrelevant issues here.

3.2.2 Key performance areas

The main KPI in this layer is the percentage of journeys within four hours door-to-door, since it is part of the long-term vision of Flightpath 2050. This falls directly within the **Capacity** KPA, since the main barrier to it is indeed the capacity of the system to bring a person from a point A to a point B in a given time and at a given price. This capacity, however, is dependent on many other factors, which can be captured in various KPIs.

The first of these answers the obvious question of whether or not the transport system can actually move the passengers in less than four hours (based on real trips), even if they theoretically can, based on schedules. In order to accomplish this, all the components of the system need to adhere to these schedules as much as possible. Hence, the **Predictability** and **Reliability** KPAs are important to ensure that the different means of transport are on time and can actually lead to low travel times.

Because different modes are involved in a single trip in general, the interfaces between them are sometimes as important as the legs themselves. "Intermodality" is sometimes used to designate the way passengers go from one mode to another. In the EU project DATASET2050, the broader term of **Interoperability** has been suggested as a name for this concept, and it is the one we will use here. In this broad concept, the idea of transition vs actual travel is central, and the various processes – queues, security, checks, boarding, check-in etc. – play a detrimental role for the passengers. For a given itinerary, the goal is thus to reduce these processes as much as possible and/or make them seamless and easy to go through.

The area of **Access and equity** is also important in this layer. Since passengers have different needs and profiles, the ambitious 4-hour target can only be reached if adequate access is available for everyone. This can be captured by various metrics, but is specifically linked to the catchment area of airports. The number of destinations within a 4-hour reach for a given population obviously influences whether or not these passengers will take the trip.

Furthermore, **Efficiency** is very important in order to evaluate the costs incurred by having the benefits delivered. Efficiency is generally a ratio between a benefit and a cost. This can turn into different measures of efficiency, whether in monetary terms or in terms of energy, CO_2 emissions, time, etc., depending on the types of benefit and cost considered. For instance, one can measure how far passengers can be moved with a given level of investment. Since energy is needed to transport people, and since its production is more or less detrimental to the environment and is costly, the energy required for a given trip should be monitored. Energy efficiency can be measured in several ways, of which some involve estimation of cost, while others of environmental impact.

Another example of efficiency is related to whether the system is close to an optimal functioning point or not. For instance, since physical constraints obviously apply, the way passengers travel with respect to the best feasible itinerary is important. This "best" itinerary can be defined in several ways. A simple one is to use the best available itinerary, but one can also use the best itinerary using the current technology level, the best itinerary in the near future, etc. In any case, comparing current travel times to better ones allows an indication of how much improvement can realistically be achieved in the short/medium term.

If overall gains in efficiency can be achieved in different ways, one of the most prominent of these is automation. Broadly speaking, automation covers any currently human-driven process that can be improved by adding more non-human cognitive or physical power to it. The introduction of automation is a subtle task, and not only from the social and philosophical point of view of the replacement of the human by the machine; it can have several detrimental effects on the processes themselves, usually linked to the interface and the respective roles of human and of machine. That is why the integration of automation should be treated as a separate subject and be monitored closely.

3.2.3 Key performance indicators

The KPIs included in this layer are presented in Table 8.

For **Access and equity**, we chose to use the "4-hour reach" KPI. This indicator computes the distance that can be reached, within Europe, from 90% of European doors in less than 4 hours. This measures roughly how well 'connected' Europe is.

In the **Efficiency** KPA, we have selected three KPIs. The first one is related to time efficiency; it is the percentage of journeys for which the ratio of the best possible journey time to the actual time of travel exceeds 80%. Note that in this formulation we assume that the best possible journey is the best available one. The second KPI is the efficiency in terms of cost. It measures how costly it is to take a passenger from origin to destination. This is obviously important in order to balance the goal with the resources available. The third indicator is related to, but distinct from, the second: it measures the energy needed to transport the passengers. Energy is obviously related to the cost of the trip, but not always; nowadays many energy-intensive modes (such as planes) can be cheaper than low-energy ones. The type of energy also matters, since its production can bring different modifications of our environment. This is partly reflected by the next KPI, which measures the level of emissions per passenger and per kilometre. Different emissions like NO_x, vapour, contrails, etc., can be brought together under the same umbrella by considering their long-term impact on the climate in terms of radiative forcing (or 'greenhouse effect'). This indicator does not capture other types of detrimental effects linked to emissions, such as micro-particulates, noise, etc.

The KPIs for **Interoperability** try to show the main issues when transferring from one mode to another. In short, we want the transition times to be as short as possible compared with the total travel time. Transition times are defined as any time spent outside of the main modes, i.e. plane, train, taxi, bus, etc. This includes walking times, for instance, but also and more importantly queuing times and waiting times. All these times are not equivalent, and more detailed indicators can be defined, see Hullah et al. (2017). A crucial time is that spent in security checks. Not only are these are considered unavoidable, they are usually stressful and lengthy, leading to greater travel times and higher levels of stress and fatigue for the travellers. The second KPI in this area measures the total time spent in security checks (including the waiting/queuing times) versus the total travel time.

The **Capacity** area includes two KPIs. The first is the main target set in Flightpath 2050: the number of journeys within 4 hours door-to-door. The target for that is 90%. We also included a crucial indicator for most passengers, which is the frequency of the transport modes during peak hours. The benefits of higher frequencies are many, and they include lower levels of stress for the travellers and greater predictability overall through better resilience, which will translate into shorter actual travel times. This is crucial for multi-modal travel, since delays can add up quite rapidly and trigger more delay downstream (e.g. missing the plane). The KPI focuses on peak hours since this is the time where most disruptions will appear and when, by definition, most passengers travel.

We selected two KPIs in the **Predictability** KPA. The first is centred on single legs, and computes the punctuality of the transport services. The second measures the predictability itself, i.e. the degree of randomness in the delays.

Table 8: Key performance indicators Layer 2

KPA	KPI	Target value	Urban passenger	Long-distance passenger	References[6]
Access and equity	4-hour reach: The distance that can be attained, within Europe, from 90% of European doors of origin in exactly 4 hours	N/A	N/A	N/A	Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
Efficiency	Time efficiency performance: percentage of journeys for which the best possible journey time/actual time of travel exceeds 0.8.	N/A	N/A	N/A	Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
	Energy efficiency of transport: average energy needed per passenger per km.	N/A	N/A	N/A	Inspired by 2
	Cost efficiency: total (supply) cost per passenger per km.	N/A	N/A	N/A	Inspired by 2
Interoperability	Transition-journey ratio: average of (time spent during transitions / total travel time for the journey)	N/A	high	medium	13, Paul and Kluge (2017), Expert interviews, Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
	Security efficiency: average of (time spent in security checks / total travel time for the journey)	N/A	high	high	Inspired by 2
Capacity	Journeys within 4 hours door-to-door	90% of journeys	medium	high	1, 2, 7, 13, Paul and Kluge (2017), Expert interviews, Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
	Frequencies: number of possible itineraries for the same OD per hour	N/A	high	medium	Inspired by Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
Predictability	Percentage of passengers arriving more than 15 minutes late at destination	N/A	high	medium	13, Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
	Variability of delay at arrival: standard deviation of delays at destination.	N/A	N/A	N/A	Inspired by Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)

[6] The numbers indicate the reference strategies outlined in Section 1 of the deliverable

3.3 Resilience and reconfiguration in mobility (Layer 3)

3.3.1 Introduction

Resilience in its most generic meaning can be defined as the ability to recover (quickly) from undesired events (ComplexWorld, 2012; Cook, A., Rivas, D., 2016). This layer examines the re-configuration aspects of mobility, i.e. how (quickly) it recovers and what the effects (perturbations) are from unexpected and undesirable circumstances (disturbances) such as bad weather, an external attack, a crisis, an ATC strike or simply a situational bottleneck. Everyday, the air transport system copes with many internal and external disruptions that put its resilience to the test. Sometimes, the resilience of the air transport system might fall short and cause significant flight delays, which has the potential to affect a number of passengers when the ability of those delays to propagate through the network is taken into account. In addition, in rare cases air transport system can suffer from more serious consequences, such as network-wide outages that dramatically affect its performance, or aircraft accidents involving one or more aircraft (such as runway or mid-air collisions). However, thanks to the resilience of the air transport system, many events go by with negligible consequences, or even none, and the system recovers within hours. It is in the interest of passengers' safe and punctual travelling experience to identify, model and understand the interdependencies of the various subsystems involved in the air transport and analyse their responses in presence of different disturbances. In particular, some of the questions we are interested in are:

- Is the system able to cope with the situation?
- How quickly?
- What is the stress?
- What is the impact?

In Flightpath 2050, the challenge concerning resilience and reconfiguration points out a fairly ambitious goal: "Flights arrive within 1 minute of the planned arrival time, regardless of weather conditions. The transport system is resilient against disruptive events and is capable of automatically and dynamically reconfiguring the journey within the network to meet the needs of the traveller. Special mission flights can be completed in the majority of weather, atmospheric conditions, and operational environments". As we can see from the previous quote, a long-term objective is to increase the resilience of the air transport system by suppressing the effects of weather and other disruptive events inherent to air transport on the system. Furthermore, this challenge includes a vision of providing passengers with an automatic system that tries to minimise their delay on their way to the final destination. It also covers trip reconfiguration in terms of passenger management, information management, and potential transfer between transport modes in the case of major disturbances. How far along are we in achieving these goals? This layer provides an initial performance framework for answering that question.

3.3.2 Key performance areas

The first KPA we cover in the resilience layer is **Cost effectiveness**. ICAO states that "the cost of service to airspace users should always be considered when evaluating any proposal to improve ATM service quality or performance" (ICAO, 2009). Having this in mind, a resilient system should have the quality of being able to account for costs that might come from occurring disruptions. Given that CAMERA's performance framework is passenger-centred, we are focusing on indicators dealing with passenger-orientated costs, whether the passengers are the ones causing (additional) costs to other airspace users or the ones suffering the costs.

The resilience of a system can be reflected in its **Capacity** as well. The capacity of the air transport system is observed through its ability to meet the needs of airspace users, and disturbances have the potential to temporarily change the capacity. Consequently, distortions in capacity impose restrictions on the traffic flow, resulting in service disruption for the passengers. Additionally, to respond adequately to the rising demand in air traffic, capacity typically has to be increased.

Predictability and **Flexibility** address several concepts of high importance for resilience as well. A highly resilient system should also be able to predict possible disruptions, be it short-term or long-term, so that the recovery actions can be promptly prepared. Being able to predict disruptions, or more so, possible consequences of disruptions that typically occur in air transport, provides passengers with fast and reliable solutions once those disruptions do happen. This is closely connected to the flexibility of air traffic, i.e. the ability to modify flight itineraries dynamically and even in later stages of flight planning. A more flexible system reflects a more resilient one, providing passengers with more options and various solutions when dealing with disturbances before or during their journeys.

The **Efficiency** of a system is a measure of its productivity, i.e. a way to compare the inputs and outputs of a system. In our case, an efficient air transport system is the one that transports passengers in safe, timely, and economical way from their origins to their desired destinations. An efficient air traffic system would observe minimal deviations from its planned performance and a small number of systematic errors, properties we also hope to find in a resilient system. Hence, looking at the efficiency of a system can inspire us to define indicators relevant to resilience and reconfiguration in mobility.

3.3.3 Key performance indicators

In the Table 9 we present the key performance indicators selected for this layer. For each of the five key performance areas several KPIs were selected, trying to keep the overall number of selected KPIs at a manageable level.

As has already been described in the introduction to this deliverable, the focus of the CAMERA project goes beyond solely the aviation sector and it looks at other modes of transport that typically occur within journeys where at least one of the legs is performed using air transport. Therefore, the mobility goals, regulations and strategies existing in other transport sectors, such as for example rail, have been taken into account when defining KPIs.

In the following, each mention of a disrupted flight should be considered according to the ICAO definition: “Flight disruption is any situation where a scheduled flight is cancelled, or delayed for two hours or more, within 48 hours of the original scheduled departure time” (ICAO, 2009). In order to reflect the European Union regulations for rail travel (EC Regulation 1371, 2007), a disrupted rail journey, is understood as one that is cancelled or delayed for one hour or more (with respect to its originally scheduled departure time). Therefore, a disrupted journey, in the context of CAMERA, is any journey with at least one of its legs disrupted. Furthermore, while defining KPIs, we were heavily guided by the vision of resilience presented in Flightpath 2050, as presented in the introduction section of this layer. On the other hand, when discussing delayed journeys and reconfiguration of trips, we refer to a trip as delayed if the delay amounts to 30 minutes or more. In accordance with this, in CAMERA we set the target for delay recovery attempts to give a final delay at no more than 15 minutes.

For the **Cost effectiveness** KPA we selected three KPIs. The first measures the percentage of passengers who claim their rights in the case of a disrupted flight. The European Commission (EC, 2013a) reports that data from airlines indicate that only 5-10% of passengers entitled to compensation (in cases of cancellation or long delay) actually claim it. The second KPI in the Cost effectiveness area addresses the buffer time an airline should use to ensure that 90% of the passengers on all flights do not arrive more than 15 minutes late. The third KPI covers the accessibility of the airport by public transport options available for that airport, measured through cost per km of the journey.

In the **Capacity** area, the first chosen KPI is the percentage of disrupted passengers on average in daily operations. In keeping with Flightpath 2050, the percentage should be as low as possible. The following two KPIs measure 'en-route' and 'turnaround' resilience using a concept developed in the Resilience2050 project. For en-route resilience, we observe the arrival delay as a function of the departure delay. The arrival delay is thus the dependent variable and departure delay the explanatory variable. A linear regression model is fitted between the two variables. The gradient of the linear fit is used to describe whether the delay is amplified or absorbed, demonstrating the capacity of the en-route phase to manage delay. A similar fit is carried out for turnaround resilience, with arrival delay as the explanatory variable, and departure delay of the next rotation, i.e. attributed to rotational and waiting for passengers (etc.) causes, as the dependent variable. As the final KPI in this area, similar to the third KPI in Cost-effectiveness, we chose to analyse the accessibility of the airport by public transport, but this time looking at the frequency of the "workload units" (WLU) passengers have at their disposal. A WLU can be a number of seats, vehicles or any other appropriate unit.

In the area of **Flexibility** we intend to address the goal of automatic and dynamic reconfiguration of journeys, as described in Flightpath 2050. Hence we chose 2 indicators that measure the successfulness of the system in reconfiguring trips (in the sense that passengers are safely transported to their desired destination). We measure the total percentage of all disrupted journeys that were reconfigured (and not, for example, cancelled), and the percentage of journeys that have been reconfigured and the passenger was notified about it automatically.

When it comes to the KPA of **Predictability**, for the first indicator we measure the impact of weather on delay occurrence by using a concept developed in Performance Review Unit (2011). Through this indicator we intend to capture general patterns of behaviour of the air traffic system by measuring the association between poor weather conditions and the amount of delay that appears under those conditions. For the second one, we measure the punctually of non-air transport modes by observing the amount of average delay in public transport (bus, train, subway, etc.).

The **Efficiency** KPA is followed through three chosen indicators. The first gives information about how many passengers with disrupted journeys have been informed about it upon the appearance of the disruption (using digital means, for example e-mails or airline apps). The second calculates the average time needed to offer 90% of all passengers with a disrupted journey possible alternatives. Lastly, we address the time it takes to find a solution for a disrupted passenger (what we refer to as recovery time), which is highly dependent on the type of disruption.

Table 9: Key performance indicators Layer 3

KPA	KPI	Target value	Urban passenger	Long-distance passenger	References[7]
Cost effectiveness	Percentage of passengers claiming their right in the case of a disrupted journey	100%	high	high	2, 10
	Minimum average buffer time required for flights to ensure that 90% of passengers arrive less than 15 minutes late at their final gate	N/A	N/A	N/A	Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
	Cost of non-air transport modes, for airport access/egress, per km of journey	N/A	low	medium	Inspired by Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
Capacity	Daily average percentage of disrupted passengers	as low as possible	N/A	N/A	2
	En-route processes delay amplification factor	< 0	N/A	N/A	Inspired by Resilience2050 (2013)
	Turnaround processes delay amplification factor	< 0	N/A	N/A	Inspired by Resilience2050 (2013)
	Frequency of non-air transport modes, for airport access/egress, expressed as WLUs* per minute	N/A	N/A	N/A	Inspired by Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
Flexibility	Percentage of disrupted journeys reconfigured	N/A	high	high	2, 7
	Percentage of disrupted journeys where all alternative travel options covering the entire itinerary are automatically sent to connected passengers	100%	high	high	2, Expert interviews, 13
Predictability	Percentage of airport departure or arrival delays exceeding 15 minutes in airports with an average ATM Airport Performance (ATMAP) of the day with a value of 1.5 or higher.	<10%	N/A	N/A	Performance Review Unit (2011). Technical note: Algorithm to describe weather conditions at European airports - ATMAP weather algorithm (version 2.3).
	Average delay of public transport used to access an airport	N/A	N/A	N/A	Hullah, P., Kirby, S., Cook, A.J., Tanner, G., Gurtner, G., Ureta, H., Cristobal, S., Gómez, I. (2017)
Efficiency	Percentage of passengers affected by disrupted journeys, who are notified thereof	100%	medium	medium	2
	Time (average) within which 90% of connected passengers with disrupted journeys are automatically notified of all alternative travel options covering the entire itinerary	5 minutes	medium	medium	2
	Average recovery time against disruptive events	N/A	high	high	1

3.4 ATM system properties and performance (Layer 4)

3.4.1 Introduction

Until the late 1980s, aircraft were controlled. They flew flight paths over a series of radio beacons that made up their route. Controllers in air traffic control (ATC) centres used radar information (if it was available) and/or procedural methods to keep aircraft separated when they came into close proximity to one another. Aircraft in non-controlled airspace were provided with aeronautical information services (AIS).

The increase in the number of flights over the years meant that the capacity of the air traffic control system to handle these flights became greatly reduced and this resulted in major delays to scheduled flights. By the end of the 1980s, it had become apparent that it was no longer enough to control aircraft flights, they and their flows had to be managed through air traffic flow management (ATFM). The term air traffic management (ATM) was used to encompass ATC, AIS and ATFM.

Within the next decade, it became apparent that this new ATM, while providing major improvements to the air traffic system, needed to be more efficient. In Europe, the European Civil Aviation Conference (ECAC) defined an "Institutional Strategy for ATM in Europe". This called for strong, transparent and independent performance review and a target setting system so that the European air traffic system could be managed more effectively.

In 1998, in response to this ECAC strategy, the EUROCONTROL organisation created the independent Performance Review Commission (PRC) to provide objective information and independent advice on European ATM performance, based on extensive research, data analysis and consultation with stakeholders, to the Agency's governing bodies. The PRC has 12 members who are appointed for their independence, ability, competence, experience and professional reputation in the fields of air traffic management, safety or economic regulation.

The PRC provides insight into actions that could lead to an improvement in ATM performance. With the support of the Performance Review Unit (PRU), it publishes an annual Performance Review Report (PRR) and quarterly online updates to these, as well as ad hoc reports on specific subjects. Its annual ATM Cost-Effectiveness (ACE) reports analyse and benchmark the cost-effectiveness and productivity of air navigation service providers (ANSPs).

The PRC is supported by the EUROCONTROL Agency's Performance Review Unit (PRU), which monitors and reviews the performance of the European ATM system on the PRC's behalf. As well as supporting the PRC, it supports the European Commission (EC) on work on the Single European Sky (SES) Performance and Charging Schemes. As part of the EUROCONTROL Agency, the PRU provides transparency in its work with all players in the industry.

3.4.1.1 The SES performance scheme

The European Commission launched the Single European Sky (SES) in 1999 (EC, 1999; EC, 2004), with the primary aim of providing a legislation-driven response to future capacity and safety needs. The second package of SES regulations (SES II), approved in 2009 (EC, 2009), was built on five pillars: safety, technology, airports, human factors, and performance. It changed the objective of SES from increasing capacity to enhancing European ATM's economic and environmental performance. This is driven by the SES Performance Scheme, which defines performance targets, for specified reference periods (RP), that require each member state to: adopt binding performance plans before each reference period; monitor the performance attained; and take corrective actions if necessary.

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[7] The numbers indicate the reference strategies outlined in Section 1 of the deliverable

The SES Performance Framework looks at five key performance areas (KPAs) related to ATM performance:

- Capacity;
- Environment;
- Flight efficiency;
- Cost efficiency;
- Safety.

To assist it with implementing this performance scheme, the EC (2010) defined the role of an advisory body known as the Performance Review Body (PRB) whose tasks include:

- defining KPAs, their appropriate KPIs, targets and alert thresholds;
- monitoring ATM performance at local and EU levels;
- preparing annual reports and other ad-hoc reports;
- assessing of the level of attainment of performance targets;
- making recommendations to the EC for improving the scheme.

It also assists national supervisory authorities (NSA) in ATM performance matters, obtains information from them for monitoring of the overall performance of the European ATM network, and assesses the consistency of their national performance plans, target and thresholds with EU ones.

In 2010, the European Commission designated the PRC, supported by the PRU, as the PRB. The designation ended on 31 December 2016 and a new PRB was appointed. The SES performance scheme reference periods are outlined in detail in Annex C.

3.4.2 Key performance areas

Of the five SES KPAs, four have been selected for the CAMERA analysis of ATM performance.

Air traffic's impact on the **Environment** and social well-being have been the subject of study, and much polemic, for many years. In fact, these environmental and social effects are one of the major challenges for the growth of the aviation industry, which has major programmes designed to alleviate these consequences. These issues can be broken down into three areas:

- Noise: While not being a true environmental effect since it leaves no physical trace, aircraft noise is a major source of annoyance to people who live near airports and underneath flight paths. It has been shown to have serious consequences for the health of such people, notably cardiovascular effects from noise-related stress and sleep disturbance. Studies have also shown that it can be responsible for cognitive impairment in children, and thus significantly impair their quality of life. However, noise only accounts for about 30% of the variance in the annoyance felt by people living near airports and it is important to remember the many other factors that make up, or can reduce, the total annoyance. Noise, which is easy to complain about, can often be used as a proxy for other complaints.
- Local air quality: Aircraft and airports are responsible for ground-level emissions of carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), ozone (O_3), particulate matter (PM10 and PM2.5), and Volatile Organic Compounds (VOC) that can lead to cardio-vascular disease, respiratory problems and asthma, bronchial and pulmonary disease and cancer, leukaemia, mesothelioma, etc. These pollutants can come from many sources: aircraft-related, airport-related, airport-user-related. Aircraft-related sources are mostly the engines, including the auxiliary power units (APU) used when the aircraft is at the stand, and de-icing solvents. Airport-related emission sources include ground-support equipment (GSE), air-conditioning systems, fire training, and power generation. Airport-users are generally responsible for car-exhaust emissions, which can be a considerable proportion of the NOx and PM emissions around an airport.

- Global emissions: Aviation is the only industry to directly inject pollutants into the upper atmosphere. Not only is carbon dioxide (CO_2) a major problem (aviation is responsible for around 15% of all transport CO_2 emissions), but high-altitude NO_x emissions affect the ozone layer. Additionally, water vapour and PM/soot creates vapour trails, or "contrails", that are involved in radiative forcing. Aircraft need a power source that has a high energy density, and so far, nothing has been found that provides as much power as jet-fuel for the same weight. Work is now at an advanced stage in finding and producing alternative fuels that have almost the same energy density but whose life-cycle carbon emission ("from well to wing") is less than that of traditional jet fuel. Several alternative fuels and production methods have now been proposed and many aircraft currently fly with a blend of alternative and regular fuels. Many of these alternatives not only produce less life-cycle carbon, but often lead to lower emission of some pollutants (PM, VOC) responsible for poor local air quality.

The **Capacity** of the air traffic system is an indicator of how many aircraft can be safely managed at a given time. It is, therefore, theoretically bounded by safety. When the system reaches its capacity, aircraft have to be delayed or forced to fly non-optimal, but less busy routes. Because of the environmental consequences of airborne delay or non-optimal routes, this generally results in delay on the ground before take-off. This is called "flow management". ATM capacity can, therefore be measured in terms of the number of minutes average air-traffic flow management (ATFM) delay per flight, or the total number of minutes of ATFM delay per month or year. There are, however, many operational and technical restrictions on this capacity that can be removed without affecting the overall safety of the system. Indeed, removing these restrictions could lead to enable both an increase in capacity and an improvement in safety. For the growth of the system it is essential, therefore, to reduce these restrictions, especially at peak times and locations.

New technology and the new operational practices it will allow can enable the ATM capacity to increase while not compromising the safety of the system or creating more impact on the environment. The enabling technologies cover communication, navigation and surveillance (CNS); information management, including system-wide information management (SWIM); and improvements to on-board avionics. As part of its Global Air navigation plan (GANP), the International Civil Aviation Organisation (ICAO) has launched a programme of Aviation System Block Upgrades (ASBU) designed to harmonise the implementation of new avionics capabilities and ATM ground infrastructure. An ASBU is a module that defines a set of capabilities for clearly defined measurable operational improvements, with the necessary equipment and/or systems in aircraft and on the ground. This provides a roadmap towards the interoperability of the global aviation system. ASBUs are defined in five-year modules starting 2013, 2018, 2023, and 2028.

European implementation of these is managed under the auspices of the Single European Sky ATM Research (SESAR) project. This was launched in 2004 as the technological pillar of the Single European Sky (SES) to define, develop and deploy the technological and operational changes necessary for the air traffic system of the 21st century. The equivalent programme in the USA is called NextGen.

The third KPA examined is **Cost effectiveness**. European en-route ATM is provided by state-based organisations responsible for the airspace over their given state. These organisations are mostly civil services or corporations of which the particular state is at least a majority, if not the sole, shareholder. They all operate in a monopoly situation for the airspace they control. The cost of this service is calculated by the EUROCONTROL Central Route Charges Office (CRCO) and billed to the airspace users that use it, on behalf of the states to which it then distributes the money collected. The amount billed depends on the time each airspace user had a plane fly through each state's controlled airspace - each state setting its own "unit rate", which is approved by all states in the system, for the cost of the service in that state. For a given flight, for each state's airspace it flies through, that state's unit rate is multiplied by the square root of one fiftieth of the aircraft's maximum take-off mass (MTOM) (in tonnes), multiplied by one hundredth of the great circle distance (km) between the entry and exit points of the flight into and out of that airspace as defined by the last filed flight-plan. The total charged for the flight is the sum of the charges per state. 2017 unit rates ranged from €19 in Malta to €105 in Switzerland (EUROCONTROL, 2018).

The CRCO billed airlines a total of €8bn in 2017 (an increase of 1.2% on 2016) for a total of 10.8bn km flown (+6.3%) by 10.5m flights (+3.8%) (EUROCONTROL, 2018). At some €800 per flight ATM costs represent some 6-7% of an airline's operating costs. The implementation of improvements in the performance of the ATM system and changes in the quality of the service provided must take into account the cost of these changes to airspace users (airlines). It is hoped that a reduction in the ratio of back-office staff to controllers, and the re-organisation of the service itself - currently performed by 38 different ANSPs - into functional airspace blocks (FAB) will go a long way towards improving the cost-effectiveness of the ATM system.

Operational **Efficiency** is the principal vector for increasing the capacity and cost-effectiveness, and reducing the environmental impact, of ATM. In an ideal airspace, airspace users would be able to fly their aircraft at the times they choose and to follow the flight paths they consider optimum to their businesses. The ability to do this is limited by many inefficiencies in the system that need, therefore, to be removed. An example of this is the route structure that imposes non-optimal trajectories on aircraft and is left over from the early days of aviation when aircraft navigates from ground beacon to ground beacon. New navigation techniques such and P-RNAV have allowed this route structure to be by-passed for a long time. However, it is still used to specify flight plans and to ensure separation between aircraft when necessary. Free routing is now available in certain sectors, allowing flight operations to plan a direct round through a sector from a given entry point to a given exit point, and this is one means of improving operational efficiency. Advanced Flexible Use of Airspace (AFUA) between civil and military users will be another.

3.4.3 Key performance indicators

The following indicators and their targets are defined in SES and SESAR documents and have been selected as CAMERA ATM KPIs. As opposed with the other layers presented, they therefore refer exclusively to flights.

Table 10: Key performance indicators in Layer 4

KPA	KPI	Target value	References
Environment	Horizontal en-route flight-efficiency of the last filed flight plan (% additional distance) ("KEP")	3.7 to 3.9%	PRB, 2018
	Horizontal en-route flight-efficiency of the flown route (% additional distance) ("KEA")	2.2 to 2.4%	PRB, 2018
	CO_2 emissions (tonnes per flight)	-0.79 to -1.6	SESAR, 2015
Capacity	En-route ATFM delay (minutes per flight)	0.24 to 0.5	PRB, 2018
	Departure delay - all causes (minutes per departure)	-1 to -3	SESAR, 2015
	Additional flights at congested airports	+0.2 to 0.4 million	SESAR, 2015
	Network throughput additional flights	+7.6 to 9.5 million	SESAR, 2015
Cost effectiveness	Average determined en-route unit cost (in €2009)	€37.77 to €42.25	PRB, 2018
	Gate-to-gate ANS cost per flight	-€390 to -€380	SESAR, 2015
Operational efficiency	Average flight time (minutes per flight)	-4 to -8	SESAR, 2015

Other PIs defined by SES, SESAR and other organisations cited that may be considered relevant for monitoring in CAMERA, or for use in further research, are given in Annex A3.

3.5 Mobility supply side (Layer 5)

3.5.1 Introduction

The "Mobility supply side" layer (Layer 5) addresses the efficient provision of (air) transport interface nodes including the right quantity and standards that are crucial to ensuring the progress towards, for example, the accommodation of 25 million flights per year. It focuses on the optimisation of services and processes within these nodes, and on the integration of air transport infrastructure with other modes, i.e. the goal is to achieve an intermodal network and related processes. This also includes the ability to integrate new (air) mobility concepts and technologies.

3.5.2 Key performance areas

The first KPA covered within this layer is **Capacity** which includes meeting the customer requirements at the required time and thus providing either sufficient capacity or using available capacity efficiently. Inadequate capacity has a negative impact on required mobility supply and consequently on passenger demand. This also incorporates the future development of mobility solutions as well as enhancements to the European transport system and whether these can be integrated accordingly, as stated in the STRIA "Integration of infrastructures, vehicles, systems and services into a truly multi-modal network". This applies to urban public transport, inter-urban or inter-regional mobility as well as to international gateways.

Another important aspect in providing an efficient and seamless intermodal network is the **Interoperability** between transport modes. As highlighted in Layer 1 and Layer 2, this KPA includes the concept of intermodal integration which, in Layer 5, refers to coherent standards across transport modes as well as the alignment of respective infrastructure in order to facilitate passengers' door-to-door journeys. Integration across modes also concerns the sharing of data across providers in order to streamline passenger processes and to react in case of disruption, as outlined in Layer 1 and Layer 3.

As outlined in the previous layers, the **Access and equity** KPA fosters the development and implementation of mobility solutions and services that are applicable to all types of user. With regard to Layer 5, the supply of mobility is strongly related to the concept of universal design. Basically, this concept implies that mobility services and products are designed so that they are accessible to all user groups, irrespective of physical impairments or individual requirements (National Disability Authority, 2018). This imposes stringent requirements on future transport systems since most of these have been designed in a way that meets the needs of only a fraction of users.

The **Security** KPA has already been highlighted in this report, and also plays a major role in the provision of transport infrastructure, services and products. However, the level of security measures in place varies widely across the different transport modes. Air transport, for example, is subject to the highest number of security measures, which affects the time passengers spend in related processes, whereas rail stations do not require travellers to pass through hand luggage checks, for example. Since security will also be of the utmost importance in the future, the transport system has to exhibit some degree of flexibility as well as capacity to incorporate new or amended security measures.

Already addressed in the previous layers, the **Efficiency** KPA is also important with regard to mobility supply. (Re-)directing passenger journeys in an efficient way has already been highlighted in Layer 3. In order to realise this a comprehensive information management system has to be provided to passengers throughout their journey.

3.5.3 Key performance indicators

The KPIs that are included in this layer are intended to represent the different key performance areas and measure the progress towards European mobility goals within each KPA. The individual KPIs are outlined in Table 11.

Regarding the **Capacity** KPA, the focus is placed on using the available capacity in the optimal way as well as being able to integrate new or amended mobility solutions efficiently. The KPI accounting for capacity utilisation therefore measures the throughput of a particular infrastructure facility (e.g. airport, rail station) in terms of vehicles or passengers being processed in a given amount of time. This KPI also gives an indication of which facilities face excess demand and hence potential congestion during certain or all hours of the day. Driven by several future challenges such as the need for emission reduction, relieving congestion in urban areas or incorporating new forms of energy option, new mobility solutions are already emerging today. Measuring how well these can be integrated into the current transport system and whether there is a benefit to society of these mobility solutions is therefore crucial. Identifying the cost of these projects as well as the expected benefits is essential in understanding the added value of these new mobility solutions.

The area of **Interoperability** is one major aspect that is highlighted in different European mobility strategies as enhancing the future transport system. In order to move towards a seamless and integrated passenger journey, several issues have to be addressed in regard to mobility supply. First, a seamless passenger journey can be provided if mobility suppliers have access to the same relevant passenger data in order to react to disruptions and delay (as addressed in Layer 3). The share of mobility providers along the passenger journey that share data among each other is therefore an indicator for the provision of a seamless journey. The latter is also provided by ensuring that passengers only have to check their baggage once during their journey instead of having to carry it from one mode to another. In order to ensure the participation of as many mobility providers as possible in sharing passenger data, a comprehensive regulatory framework assigning responsibilities and liabilities is required. CAMERA considers different transport modes but puts an emphasis on air transport, accounting for the intermodal integration of airports is thus of particular interest. The connection to other (high-speed) transport modes directly at airport terminals is a good indication for the degree of integration between modes.

In terms of the **Access and equity** KPA, it has been highlighted that the application of a universal design ensures the access to mobility for all kinds of user. There are various steps that can be undertaken to ensure this and the KPIs applied in this performance framework contribute to measuring the progress of some of these steps. First, the use of the same understandable and redundant ways of presenting information across all transport modes has to be ensured. Second, barrier-free access to transport infrastructure and vehicles is of high importance in order to make mobility feasible for all user groups.

Considering the **Security** KPA, one indicator is included here to measure progress towards a seamless European transport system. Since security standards differ widely across transport modes, a common set of standards across the entire door-to-door journey would be feasible, also ensuring that potentially time-consuming processes during changes between mode are reduced or even eliminated.

The **Efficiency** KPA is represented by one indicator as well which accounts for the provision of seamless information throughout the entire passenger journey. A part of mobility supply is the provision of real-time information to customers along the journey. Assessing how many trips this type of information is available for is therefore an indicator of how far away the European transport system is from this target.

Table 11: Key performance indicators Layer 5

KPA	KPI	Target value	Urban passenger	Long-distance passenger	References[8]
Capacity	Capacity utilisation: Capability of transport infrastructure to withstand disruptions and absorb disturbance	N/A	N/A	N/A	11, 13
	Integration of new or amended mobility solutions: Cost of infrastructure implementation (time and monetary) relative to overall benefits for society	≤1	N/A	N/A	2, 11
Interoperability	Data and information sharing: Share of mobility providers sharing data across the passenger journey	≥90%	N/A	N/A	13
	Regulation and liabilities: Share of mobility providers automatically applying the same regulatory framework	≥90%	N/A	N/A	2, 10, 11, 13, 14
	Baggage handling: number of times passengers have to check/ transfer luggage during a door-to-door journey	1	medium	high	13
	Single ticketing: Share of mobility providers applying the same booking and ticketing tool enabling automatic booking and ticketing of an intermodal journey in a single transaction	≥90%	N/A	N/A	2, 9, 11, 13
	Intermodal integration: Share of airports having integrated facilities for changes of transport modes (mainline/ light rail or long-distance bus station within a maximum ten minutes of airport terminal)	≥90%	low	high	2
Access and equity	Use of different ways for redundant presentation of essential information (pictorial, verbal, tactile) across all transport modes	Availability of three different ways of representing information	high	high	9, 13, National Disability Authority (2018)
	Share of availability of barrier-free access across all transport modes during door-to-door passenger journey	100%	high	high	3, 4, 5, 13
Security	Share of transport modes applying the same comprehensive security standards	≥90%	N/A	N/A	10, 13
Efficiency	Provide automated on-the-go real-time itinerary information travellers at any stage of the journey: Share of availability of real-time itinerary information for all trips	≥90%	high	high	2, 3, 4, 5

[8] The numbers indicate the reference strategies outlined in Section 1 of the deliverable

4 *Initial performance framework*

The following initial performance framework has been developed from the various steps outlined in this deliverable. The left hand side shows the five mobility layers within CAMERA, across which 11 different key performance areas (KPA) are assigned. A KPA can be relevant within different mobility layers, e.g. **Access and equity** occurs in Layers 1, 2, 5. Each of these KPAs then contains a number of key performance indicators (KPIs).

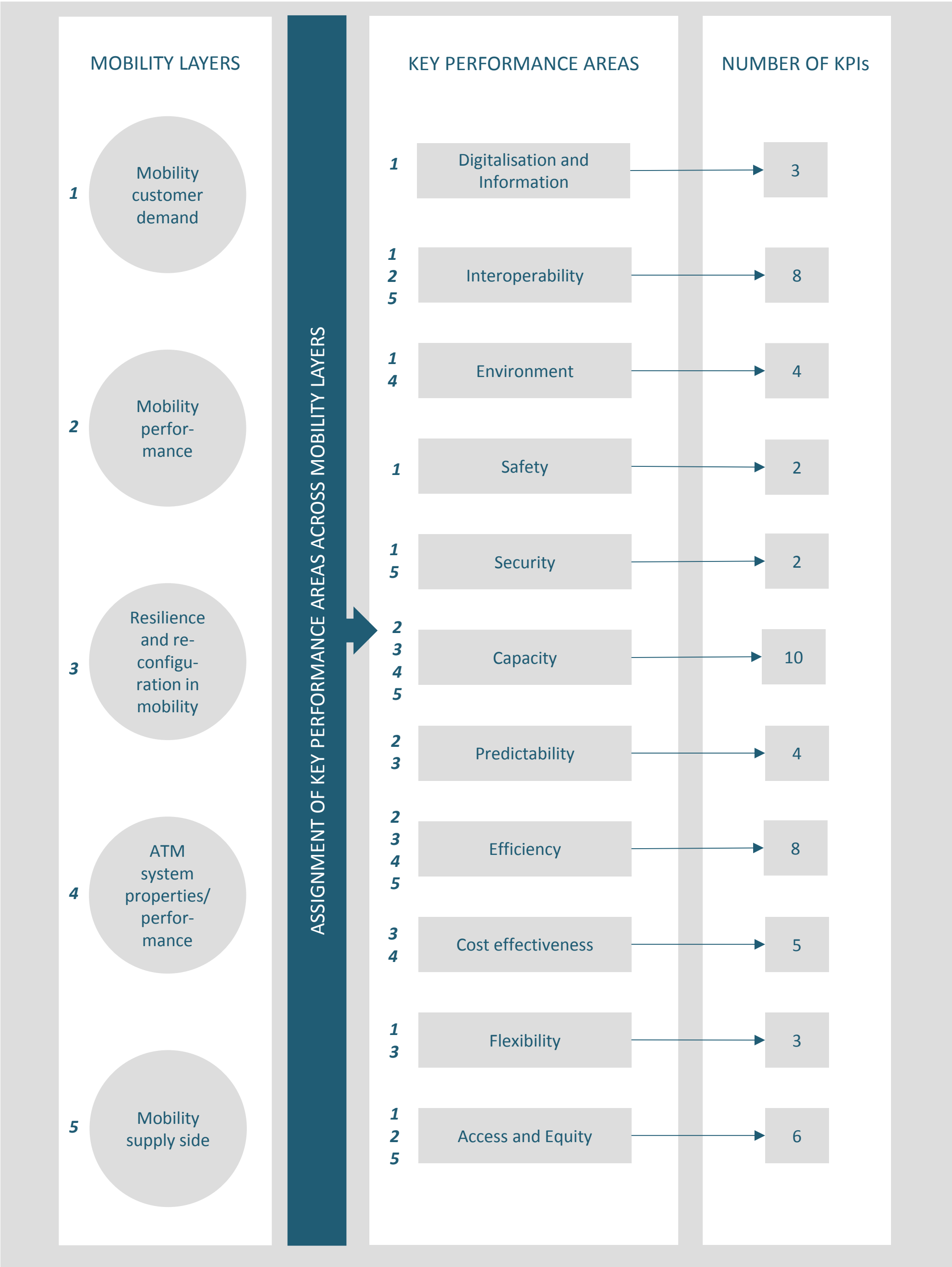

Figure 7: Initial performance framework

Since the performance framework has been derived based on European mobility goals for the future, the analysis of the KPIs yields a detailed picture how well these goals are currently being addressed and in which areas further research and innovation is required. With regard to the "Journeys within 4 hours door-to-door" KPI (Layer 2, KPA Capacity), the target value requires that 90% of European passengers be able to complete their door-to-door journey within 4 hours. Assessing the share of passengers that are currently able to conduct their journey within this timeframe provides the delta the European transport system is facing.

These KPIs will also be applied in the further course of the project to match projects and initiatives with the different topics. From this, a detailed overview of the research landscape can be obtained showing which goals, or key performance areas, are well covered by research and innovation activities, and which need more focus in the future.

5 Research needs and next steps

5.1 Identified research, innovation and investment needs

Several high-level research and innovation (R&I) and investment needs have been identified within the work on the performance framework and as an outcome of the expert interviews conducted for Layer 1.

One aspect where more R&I might be needed are single platforms. On the one hand, there seems to be a need for a European Travel Agent, a single platform that really provides single ticketing, booking solutions and travel packages for passengers. Such platforms could also regulate social interests, such as offering detours to avoid overcrowded stations and intersections. On the other hand, to foster B2B interaction, a Europe-wide platform for mobility providers to exchange such things as real time travel information or possible compensation in case of disruption might be beneficial as well. In this sense, European transport data regulations and policy making could support the development of such platforms and provide a standardised process for data sharing between different providers. More investment for data analytics also seems to be necessary.

Another aspect is the interaction of city planning and mobility planning. A long-term view of city and infrastructure planning, such as understanding the cities of tomorrow and planning these according to new modes of transport, as well as understanding how future modes could be integrated into our current European transport system (e.g. Urban Flying Vehicles), is important. To incorporate this long-term view, it could be necessary to focus less on optimising and improving our current transport system and more on the novel transport modes and concepts of tomorrow. Besides, there are too many cars in European cities and work should be towards a modal shift from privately owned vehicles to using more public transport and shared transport options, for instance, as a possible access and egress mode for airports. More research should also be conducted into what kind of incentive is needed to really change the travel behaviour of passengers towards using public transport, and what factors, such as sustainability and social responsibility, really drive this change.

At the airport itself, more standardisation is needed as well as an exchange of data and bio-metric information between airports to improve the travel experience for passengers in terms of seamlessness. Safety regulations are necessary for reducing effort and time at security and border controls. As the open space around airports will become denser, airports should also be embedded in their surroundings.

In terms of investments, a greater investment volume is required, and more risk-investment, broadly diversified in new start-ups, tech companies, technology and services around travel. Universities and research institutes that conduct research and test new technologies should have better support. In the overall transport sector, a change of mind in how to develop and test new products might be necessary. We need smaller but faster testing, such as in forms of rapid prototypes (vs. long-term and very expensive mobility projects that take too long).

Other questions to be addressed in further research could be how to bridge social and human needs with economic interests; how to create a fair mobility system in Europe; and how to use resources efficiently. Further R&I should be performed on electrification and automation.

5.2 Integration with following deliverables

We conclude this section with a brief review of the integration of this document with following deliverables:

- D3.1: Mobility research assessment and modelling: guidelines and handbook
- D4.1: Gaps, bottlenecks and results: the methodology

In D3.1, we will report specifically on the approach for collecting the performance and impact information from various research initiatives, capturing and modelling the different quantitative data from WP2, and taking account of the KPIs identified in D2.1 for use in CAMERA. D3.1 will further define the performance framework, and the modelling capabilities and approach, using Mercury. In WP4 we analyse the output of the mobility model described in D3.1, in order to identify gaps and bottlenecks in European mobility research that may impede the high-level goals set, for example, by Flightpath 2050. In particular, D4.1 will report on the methodology that will be used to identify these gaps and bottlenecks, and will decide upon the scenarios to be simulated by Mercury, determining which KPIs tabled in D2.1 will actually be computed in Mercury. It is anticipated that these KPIs will be further classified as follows:

- Class 1: can be fully quantified by Mercury;
- Class 2: could be partially estimated by Mercury (e.g. through a relationship between a Class 1 and Class 2 KPI in the literature, e.g. travel mode and comfort, respectively);
- Class 3: cannot currently be estimated by Mercury (e.g. no data and/or not implemented).

With regard to the topic modelling that will be reported in D3.1 and D5.3, any new indicators (KPIs) that are suggested through these results will be reported in D4.1 and integrated into the methodology of both D3.1 and D4.1.

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A1 Overview European mobility strategies

No. of mobility strategy	Main points
1, 2	• European citizens are able to make informed mobility choices and have affordable access to one another, taking into account: economy, speed, and tailored level of service. Travellers can use continuous, secure and robust high-speed communications for added-value applications. • 90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours. Passengers and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on-time. • Flights arrive within one minute of the planned arrival time regardless of weather conditions. The transport system is resilient against disruptive events and is capable of automatically and dynamically reconfiguring the journey within the network to meet the needs of the traveller if disruption occurs. Special mission flights can be completed in the majority of weather, atmospheric conditions and operational environments. • An air traffic management system is in place that provides a range of services to handle at least 25 million flights a year of all types of vehicles, (fixed-wing, rotorcraft) and systems (manned, unmanned, autonomous) that are integrated into and interoperable with the overall air transport system with 24-hour efficient operation of airports. • 5. A coherent ground infrastructure is developed including: airports, vertiports and heliports with the relevant servicing and connecting facilities, also to other modes.
3, 4, 5	Shift2Rail Joint Undertaking (S2R JU) is a new public-private partnership in the rail sector, providing a platform for cooperation to drive innovation (within the Horizon 2020 programme); S2R JU will pursue research and innovation activities in support of the achievement of the Single European Rail Area (SERA) and improve the attractiveness and competitiveness of the European rail system; five key “Innovation Programmes”: • cost-efficient and reliable trains, including High Speed trains and high-capacity trains; • advanced traffic management & control systems; • cost-efficient and reliable high capacity infrastructure; • IT Solutions for Attractive Railway Services; • Technologies for Sustainable & Attractive European Freight. Rail Vision 2050 • Providing access to mobility services for every European individual • Efficient and barrier-free interchanges between transport modes • Delivery of tailored, on demand integrated end-to-end mobility solutions • Providing access to real time personal communication for passengers • Data privacy management • Extension of high-speed rail networks • Metros and light rail as the core of public transport for large volumes of passengers
6	• Dealing with rapid urbanisation and population growth: linking major urban hubs and creating multi-modal local transport systems. Rail service should be able to cross borders without delays or technical barriers, providing a competitive option to air or road travel, particularly for interurban journeys and commuting into large urban areas. • Technological progress will be one of the major drivers of change for the railway sector: Advances in nanotechnology in particular will lead to lighter, stronger, smarter and greener materials. Intelligent robots and drones play a greater role in the inspection of infrastructure such as tunnels and bridges. Due to automated passenger trains designed for speed and operational safety rail will be more competitive and will be less reliant on government subsidies. Ticketless technology will remove gate-lines in stations and payment processed automatically when the journey is taken. Integrated journey apps will provide a seamless journey planning tool, which makes it possible to book and pay for journeys across all modes. Freight pipelines will transport goods and luggage safely and rapidly with low maintenance needs and costs. Smart and integrated mobility will provide accurate real-time information and optimal pricing. • Energy and resources: There will be a shift towards alternative forms of fuel lowering transportation costs significantly and transforming the global economy. By 2050 there will be a better application of a circular economy - where used materials are recycled back into the production stream, reducing waste and increasing efficiency. • Stations will become destinations and lifestyle centres that further blend our commute with our lives. People are increasingly using stations, not just as places to catch a train, but as centres for leisure and business. Station office suites and virtual shopping walls are examples to fulfil the passengers' needs besides travelling.
7	ERTRAC Vision 2050 • Walking, cycling, collective and shared mobility services forming the backbone of the urban mobility transport, complemented by private vehicles

	• Mobility is higher but fluent, inclusive and sustainable. • Encouraging sustainable and healthy mobility behaviour thanks to informed choices. • Mobility on demand including Carsharing and Ridesharing. • Improved utilisation of shared vehicles and new technologies have released former parking areas and other infrastructures for new use. • Intelligent and dynamic access regulation. • Smart, automated and dynamic parking management and allocation integrated with smart charging. • Pro-active traffic and incidents management. • Emission free in urban areas. • Smart city logistics, building a link with passenger transport and long distance freight transport. • Trans - European mobility control supports pro-active, user-centric and integrated, door-to-door mobility of people and goods. • Adaptive and flexible traffic and transport management systems across all transport modes. • Performance based standards determine access of freight vehicles to the road network. • Physical and digital infrastructure services across Europe are appropriately equipped for automated vehicles, linking to international standards. • Infrastructure services across Europe are on “pay as you use” basis. • Construction and maintenance practices are automated, leading to high cost-efficiency and minimal works related safety risks and congestion. • Fully multimodal mobility offerings including trip planning, pricing and payment. • Connectivity everywhere and at any time with stable connection and data rates. • Communication between vehicles and infrastructure to optimize traffic flow, traffic management and safety. • Mobility as a service regardless of ownership. • Predicted demand from individual behaviours, enabling appropriate modal capacity and demand management. • Digital technology for vehicle access regulation, fee payments and prioritisation. • Data privacy and international standards for data exchange and connectivity. • Highly automated vehicles for the inclusion of vulnerable users and people with reduced mobility (PRM). • Accidents and delays are extremely rare and delays automatically resolved. • Harmonized legal frameworks for automated vehicles. • Nearly zero accidents and injuries due to safety functions and automated driving functions in fully connected vehicles, road users and infrastructure. • Optimised and intuitive Human-Machine Interface (HMI) following the idea of cognitive safety. • Safe and well maintained physical & digital infrastructure. • Dedicated traffic spaces for different road users where sensible. • Improved levels of in- and post-crash safety in the remaining collisions. • Secured privacy. • Safety and security features impossible to attack and misuse. • Continuous maintenance of software and system updates constantly improving their performance. • Systematic verification & validation of cyber physical systems. • Resilience: highly automated management systems to minimise the impact of incidents and accelerate recovery.
8	• Safe, sustainable and efficient waterborne operations: "zero accidents" target, "low emissions" vessels and waterborne activities • Competitive European maritime industry: effective waterborne operations • Manage and facilitate growth and changing trade patterns: interoperability between modes (transfer nodes, open IT systems, promoting intermodal transport, intermodal services), integrated ICT solutions
9	Vision 2030 describes values thath should be integrated into a single visualisation, addressing the following goals: inclusive, seamless, sustainable. • Urban design encourages active modes • Personalised navigation systems • Mobility services provide reliable connections • Incentives for passengers, drivers and shippers • Universal design enables vehicles, infrastructure and services usable by all • Cars are shared and electrified and provide high safety • Transport operators and supply chain refer to a common open data platform • Smart connected traffic management • Last mile delivery becomes sustainable • Safe and accessible routes are continuous • Cyber-security is implemented on a systemic level • All users can shift easily from any sharing service to a public transportation mode

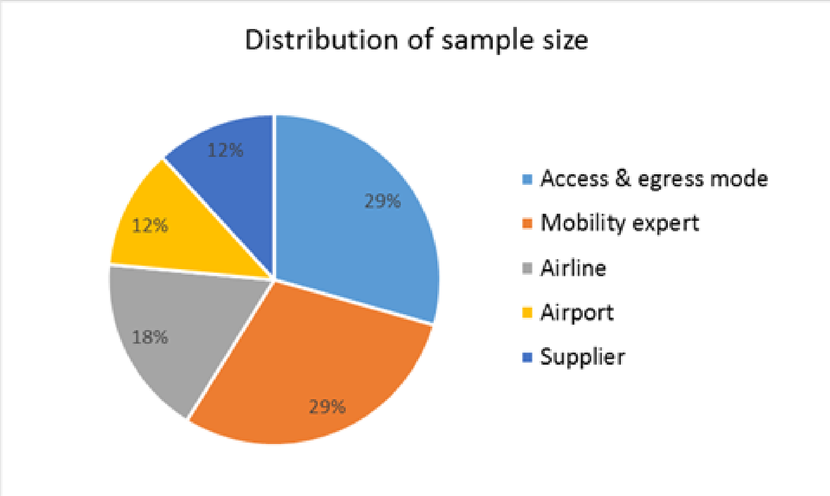
10	1. Single European transport area: • Further consolidation and expansion of trans-European transport network; convergence of rules and regulations; implementation of Single European Sky, single European railway area, facilitating and improving maritime transport; • Alignment of job quality and social agenda; • Cooperation in the field of transport security and safety (e.g. civil aviation safety strategy, SafeSeanet), harmonisation of safety certification in rail transportation; • Seamless door-to-door mobility (quality, accessibility, reliability), optimisation of intermodal chains; • Harmonisation of passenger rights. 2. Innovation: • Introduction and implementation of new technologies for vehicles and traffic management to reduce emissions; investment decisions and implementation of respective strategic research agenda; • Smart mobility systems (SESAR, ERTMS, SafeSeaNet, RIS, ITS), interoperability and interconnectedness, vehicle propulsion and alternative fuels; • Establishment of regulatory framework, standardisation and interoperability requirements; • Promoting and incentivising sustainable mobility behaviour, seamless intermodality; • Reducing urban congestion and emissions. • Reduction of greenhouse gas (GHG) emissions by transport sector by 60% by 2050 (compared to 1990 levels); by 2030 reduction of around 20% below 2008 level. 3. Infrastructure, pricing and funding: • Establishment of core network corridors for high-density and efficient transport flows; efficient multimodal combinations; • Alignment of eastern and western European infrastructure standards; • Widespread application of information technology tools; • Improvement and establishment of multimodal links and multimodal terminals; • Internalisation of externalities, elimination of tax distortions and unjustified subsidies; • Charging structure for different transport modes to foster sustainable behaviour; • Greater consistency across different transport modes, i.e. create level playing field.
11	Network and traffic management systems • Multi-modal system and development of multi-actor organisational and business models with shared responsibilities • Integration of infrastructures, vehicles, systems and services into a truly multi-modal network • Cross-modal topics: access to data, streamlining administrative boundaries, flexibility, resilience and the ability to recover from disruptions Vehicle design and manufacturing • Passenger-centric modular design transport vehicles Low-emission alternative energy for transport • Efficient use of advanced biofuels, fossil fuels blended with renewable fuels as well as pure renewable fuels Smart mobility and services • Ensuring an integrated transport system • Autonomous vehicle technology will blend with mobility as a service • Integrate drones and low-altitude aerial mobility in the transport system • Stable operational framework for new urban mobility • Develop integrated mobility systems • Share data and infrastructure • Support future interoperability (user devices, infrastructure and vehicles) • Enable real time information and operation across public and private service providers Transport infrastructure • Prepare the ground for intermodality, synchromodality, interoperability and integration of transport system from a customer perspective • Improve the capacity of transport infrastructure to withstand disruptions, absorb disturbance and adapt to changing conditions under extreme circumstances • Maximise asset utilisation for transport infrastructure (capacity) Cooperative, connected and automated transport • Research need to understand related risks of transport cybersecurity • Develop acceptance criteria for operation of different types of autonomous vehicles, including users' confidence when no "driver" is present
12	Research and innovation roadmaps: • Sustainable, safe and secure supply chains

	• Corridors, hubs and synchromodality • Information systems for interconnected logistics • Global supply network coordination and collaboration • Urban freight
13	Main findings • Collaboration between different mobility stakeholders • Common standards and targets • Roadmaps for the implementation of physical infrastructure • Digital infrastructure to access mobility data (towards single ticketing and single point of contact)
14	First Dimension: Visionary Strategy and Ecosystem • Establish a stable and accountable regulatory framework for public transport, incorporating all of the stakeholders. • Develop a visionary urban mobility strategy and master plan ensuring the right balance between stretch and achievability • Develop an integrated approach for transport planning and other urban policies to shift from isolated decision-making toward integrated urban management Second Dimension: Mobility Supply (solutions and lifestyle) • Develop competitive position of public transport by evolving from “transport provider” to “solution provider” and focusing on customer needs • Upgrading commercial offering on transport nodes • Encourage interoperability and develop multi-modal packages • Develop Integrated mobility platforms Third Dimension: Mobility Demand Management • Engage with citizens and the business community • Introduce traffic-calming measures• Introduce pricing measures • Enforce parking policy as a critical instrument to steer mobility choices • Define appropriate land-use policies (long term) • Encourage businesses to develop an active corporate mobility strategy Fourth Dimension: Public Transport Financing • Focusing on a gradual improvement in service offering quality and ensure transparency of fare adjustments • Providing bundles of services targeting different customer groups at different prices • Explore opportunities to exploit public transport assets • Prioritise public funding for capital investments • Further stimulate partnerships with private investors
15	• Clean, efficient and electrified propulsion • Advanced driver assistance systems (ADAS), connectivity and automation to increase safe and convenient road transport • Charging infrastructure for transport and cyber-security hardware • Smart mobility services to optimise personal mobility and to increase traffic volume
16	• Towards free-flowing towns and cities: Alternatives to private car use, such as collective transport, walking, cycling, should be made attractive and safe. Citizens should be able to switch between modes easily. Possible solutions range from good connections between modes, good parking facilities outside city centres, urban charging schemes, better traffic management and information, carpooling and car-sharing, and efficient freight transport • Towards greener towns and cities: Development of new and clean technologies (energy efficiency, alternative fuels) supported by green procurement, traffic restrictions and green zones (pedestrianisation, restricted access zones, speed limits, urban charging, etc). • Towards smarter urban transport: Intelligent Transport Systems (ITS) and urban traffic management and control applications present a potential added value for an efficient management of urban mobility, including freight distribution. Smart charging systems, better traveller information and the standardisation of interfaces and interoperability of ITS applications in towns and cities are part of the solution • Towards accessible urban transport: innovative solutions for high quality collective transport, intermodal terminals for collective transport, and good links between suburban and urban transport networks. • Towards safe and secure urban transport: Possible solutions must cover behavioural, vehicle and infrastructure aspects as well as a strict enforcement of traffic rules
17	• Cycling should be an equal partner in the mobility system. Users pay for the full external costs of motorised transport while the societal benefits of active mobility are fully taken into account in transport planning and investment decisions. In addition, it will show the path towards prioritising cycling over individual motorised transport.

- Cycle use in the EU will increase by 50% in the decade from 2019/2020–2030. Its share in the transport modal split will be at least 12%, which means 0.48 cycle trips per person per day on average.
- The rates of fatalities and seriously injured among cyclists (per kilometre cycled) will be halved in the decade 2019/2020–2030.
- The EU should double its investments in cycle projects to EUR 3 billion during the Multiannual Financial Framework 2021–2027 (from EUR 1.5 Billion in 2014–2020) and aim for another doubling to EUR 6 billion during the 2028–2034 period.

A2 Expert interviews

A. Expert interviews: Details on sample of experts



Sample type	Transport provider / expert[9]
Access & egress mode	VBB (Verkehrsverbund Berlin Brandenburg)
Access & egress mode	BMW Group
Access & egress mode	BMW
Access & egress mode	Wiener Linien
Access & egress mode	Deutsche Bahn
Airline	Airline (anonymised)
Airline	Lufthansa Group
Airline	Swiss
Airport	Munich Airport
Airport	Brussels Airport
Supplier	Airbus
Supplier	Supplier automotive sector (anonymised)
Mobility expert	Automotive Researcher (anonymised)
Mobility expert	Mobility Consultant (anonymised)
Mobility expert	Design Thinking Expert (anonymised)
Mobility expert	Digitalisation and Travel Experts (anonymised)
Mobility expert	Rover (Dutch Passenger Association)

[9] Some interviewees are anonymised upon their request

A3 SES performance scheme reference periods

SES performance scheme reference periods

The first RP (RP1) ran from 2012 to 2014 and the second (RP2) from 2015 to 2019. Subsequent reference periods will be fixed to five years (EC, 2010; EC, 2013). Indicators are defined for each KPA for each RP. These can be simple performance indicators (PI) for monitoring performance, or they can be key performance indicators (KPI) with a specified target.

A3.1 Reference period 1

The performance plans for the first reference period (RP1) were approved in July 2012, with monitoring and reporting to be undertaken from 2012 to 2014. RP1 defined KPIs in four of the five KPAs: safety, environment, capacity, and cost-efficiency. EU-wide targets were set for KPIs the three non-safety KPAs:

Environment	Average horizontal en-route flight-efficiency of the last filled flight plan trajectory (% additional distance)
Capacity	En-route ATFM delay attributable to ANS (minutes per flight)
Cost-efficiency	Unit price (Determined en-route unit cost)

Performance in the Safety KPA was monitored to ensure that high safety levels were maintained or improved.

An analysis of this first reference period showed that its benefits significantly outweighed its costs, providing benefits of €3.4bn, for running costs of €87m over the period 2012-2015 (EC, 2018). This analysis showed that ATFM delays decreased (less than expected), and flight efficiency and cost efficiency improved. The 'true cost' to airspace users fell over RP1 but cost-efficiency improvements were moderate and mostly due to increased traffic (thereby reducing the unit cost) rather than real reduced costs of ANS.

A3.2 Reference period 2

The second reference period (RP2) runs from 2015 to 2019. It includes binding EU-wide and Functional Airspace Block (FAB)-based performance targets for KPIs in all four of the above KPAs, and revised performance & charging regulations. The European air-traffic Network Manager is an integral part of the performance scheme in RP2. The RP2 approach to performance covers the entire chain of air navigation services from "gate to gate", and has a clear link to new investments and the major overhaul of systems under the EU ATM Master Plan, including performance planning at the FAB level.

New KPIs were added compared with RP1 and local targets, either national or FAB-based, were defined for some. The key performance indicators for target setting in RP2 are given below.

Key Performance Area	Key Performance Indicator for target setting	EU Target	FAB Target	National Target
Safety	Effectiveness of safety management (EoSM)	Y	Y	
	Application of the severity classification based on the Risk Analysis Tool	Y	Y	
	Level of presence/absence of "just culture"		Y	
Environment	Average horizontal en-route flight-efficiency of the last filled flight plan trajectory (% additional distance)	Y		
	Average horizontal en-route flight-efficiency of the the actual flown trajectory (% additional distance)	Y	Y	
Capacity	En-route ATFM delay attributable to ANS (minutes per flight)	Y	Y	
	Arrival ATFM delay attributable to terminal and airport ANS caused by landing restrictions at the destination airport (minutes per flight)	Y		Y
Cost-efficiency	Unit price (Determined en-route unit cost)	Y	Y (Charging zone)	
	Unit price for terminal ANS	Y (from 2017)	Y (Charging zone)	

A3.3 Reference period 3

The third reference period (RP3) will run from 2020 until 2024 and is the final development of the SES Performance Scheme. According to the Industry Consultation Body (ICB), the targets or objectives of RP3 are scheduled to be decided in 2018. Little information is currently available on this, although it will to encompass the enhancements and lessons learned from RP1 and RP2. A first white paper has been developed on the proposed performance strategy for RP3 and stakeholders have given their feedback on this. This will lead to the development of the final set of indicators to be monitored in RP3. It has been suggested that RP3 include an indicator addressing the issues of inter-dependencies between KPAs/KPIs that have not been formally analysed in the previous RPs. The PRB has produced a set of EU-wide target ranges for RP3 to assist in this development (PRB, 2018).

Other performance frameworks

Before the SES performance scheme came into being, and afterwards as well, other organisations have defined KPAs and KPIs/PIs for measuring the performance of the air traffic system. These include:

- ICAO, which defined 11 KPAs in its Global ATM operational concept in 2005 (ICAO, 2005):
    - Access and equity, Capacity, Cost-effectiveness, Efficiency, Environment, Flexibility, Global interoperability, Participation by the ATM community, Predictability, Safety, and Security;
- CANSO published a set of recommended KPIs for measuring ANSP's operational performance in 2015 (CANSO, 2015) focusing on:
    - Capacity and efficiency, and Predictability.
- CANSO also regularly reports on cost-effectiveness of ANSPs using some basic KPIs;
- EUROCONTROL's Performance Review Report (PRR) 2015 (EUROCONTROL, 2016) proposed several PIs supplementary to those in the SES performance scheme in the KPAs of:
    - Safety, Capacity, Efficiency, Environment, and Predictability;
- EUROCONTROL also uses some economic performance indicators in its PRRs and ATM Cost-Effectiveness (ACE) reports;

- the SES ATM Research (SESAR) Joint Undertaking (SJU) has its own performance framework in the SESAR 2020 project based on eight of the KPAs from the ICAO framework (SESAR, 2015):
    - Access and equity, Capacity, Cost-efficiency, Environment, Flexibility, Predictability and punctuality, Safety, and Security.

These performance frameworks have all been discussed in detail by the Horizon 2020 SESAR Apache and Intuit projects, and the present project will not repeat the excellent work of these two. The reader seeking further information is referred in sections 2 and 3 of Apache deliverable 3.1 (Apache, 2017) and sections 2 and 3 of Intuit deliverable D2.2 (Intuit, 2016).

Other KPIs to be considered in the further course of the project are:

KPA	KPI	RP2 Target value	Reference
Environment	Horizontal en-route flight-efficiency of the last filed flight plan (% additional distance) ("KEP")	2.6% in 2019	EC, 2014
	Horizontal en-route flight-efficiency of the flown route (% additional distance) ("KEA")	4.1% in 2019	EC, 2014
	CO_2 emissions (tonnes per flight)		
Capacity	En-route ATFM delay (minutes per flight)	≤0.5	EC, 2014
	Departure delay - all causes (minutes per departure)		
	Additional flights at congested airports		
	Network throughput additional flights		
Cost-effectiveness	Average determined en-route unit cost (in €$_{2009}$)	€56.64 for 2015 €54.95 for 2016 €52.98 for 2017 €51.00 for 2018 €49.10 for 2019	EC, 2014
	Gate-to-gate ANS cost per flight		
Operational efficiency	Average flight time (minutes per flight)		

KPA	KPI	Defined by
Environment	Reduction in average flight duration	SESAR
	Number of people exposed to significant noise in a 3-year sliding window	ICAO, SESAR
	Number of people affected by significant pollutant concentrations	SESAR
Capacity	%age of flights with more than 15 minutes en-route delay	SES
	Peak airport arrival capacity	SESAR
	Airport time to recover from non-nominal position	SESAR
Cost-effectiveness	Average gate-to-gate unit costs	SES
Operational efficiency	Average travel time between city pairs	CANSO

The Horizon 2020 SESAR Apache project proposed some new PIs (APACHE, 2017). The following have been selected for monitoring in CAMERA, or for use in further research:

KPA	KPI
Capacity	Average flow management arrival delay
	Maximum throughput capacity per sector/FAB
	Minutes of delays
	Number of cancellations
Cost-effectiveness	En-route unit economic costs for the AU
Environment	Strategic ATM inefficiency on trip fuel (or emissions)
	Tactical ATM inefficiency on trip fuel (or emissions)
Operational Efficiency	Average (maximum) excess travel time per passenger/flight city pairs