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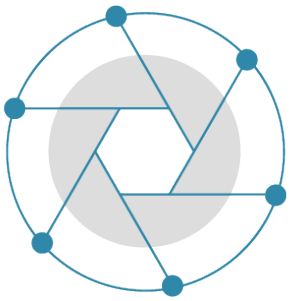

CAMERA

D2.2

D2.2 PERFORMANCE FRAMEWORK IMPLEMENTATION

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Contributors: Ulrike Schmalz (BHL), Annika Paul (BHL), Damir Valput (INX), Andrew Cook (UoW), Inés Gómez (INX), Peter Hullah (ECTL), Micol Biscotto (DBL), Paula López-Catalá (INX)

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H2020 - CAMERA

CAMERA – COORDINATION AND SUPPORT ACTION FOR MOBILITY IN EUROPE: RESEARCH AND ASSESSMENT

CAMERA Consortium

1	innaxis	INNAXIS (INX)	Contact: Paula López-Catalá plc@innaxis.aero
2	UNIVERSITY OF WESTMINSTER	University of Westminster (UoW)	Contact: Andrew Cook cookaj@westminster.ac.uk
3	EUROCONTROL	EUROCONTROL (ECTL)	Contact: Peter Hullah peter.hullah@eurocontrol.int
4	Bauhaus Luftfahrt Neue Wege.	Bauhaus Luftfahrt e.V. (BHL)	Contact: Ulrike Schmalz ulrike.schmalz@bauhaus-luftfahrt.net
5	deepblue CONSULTING & RESEARCH	Deep Blue srl (DBL)	Contact: Micol Biscotto micol.biscotto@dblue.it

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Table of Contents

1 Abstract

This Deliverable 2.2 (D2.2) covers the high-level details of tasks from Workpackage 2 (WP2) executed along CAMERA. The CAMERA Performance Framework with its five layers, key performance areas and key performance indicators is presented. It is elaborated how the framework, which was finalised in 2018, is implemented along the CAMERA project. The outcomes as such are reported in the Mobility Reports 1 to 4. Further, the deliverable summarises how the CAMERA Performance Framework is used outside of the CAMERA project for dissemination purposes. Based on newly published strategic documents such as The European Green Deal or the Sustainable and Smart Mobility Strategy, it is also shown how the CAMERA Performance Framework could be developed further to tackle emerging trends, current challenges and mobility goals in a better way, such as environmental and digitalisation goals and the usage of data and artificial intelligence models. Lessons learnt and improvements done to the methodology and general project approach are also discussed.

2 List of Abbreviations

4HD2D = four hours door-to-door

ACARE = Advisory Council of Aviation Research in Europe

AI = artificial intelligence

ART = Agency Research Team

ATC = air traffic control

ATM = air traffic management

CAMERA = Coordination and Support Action for Mobility in Europe: Research and Assessment

CORDIS = Community Research and Development Information Service

CO_2 = carbon Dioxide

dB = decibels

DOI = digital object identifier

D&I = digitalisation & information

D2D = door-to-door

D2K = door-to-kerb

EC = European Commission

EASA = European Union Aviation Safety Agency

EEA = European Environment Agency

EU = European Union

FP7 = 7th Framework Programme for Research and Technological Development

GDPR = General Data Protection Regulation

H2020 = Horizon 2020

ICAO = International Civil Aviation Organization

KPA(s) = key performance area(s)

KPI(s) = key performance indicator(s)

km = kilometer

kt = kiloton

LDA = latent Dirichlet allocation

MaaS = Mobility as a Service

NLP = Natural Language Processing

NLR = Royal Netherlands Aerospace Center

no. = number

NO_x = nitrogen oxide

pax = passenger

PF = performance framework

R&I = research and innovation

SAF = sustainable aviation fuels

SESAR = Single European Sky ATM Research Programme

SLOCAT = Partnership on Sustainable, Low Carbon Transport

SRIA = Strategic Research and Innovation Agenda

STRIA = Strategic Transport Research and Innovation Agenda

S2R = Shift2Rail

TEN-T = Trans-European Transport Network

TRANSIT = Travel Information Management for Seamless Intermodal Transport

TRIMIS = Transport Research and Information Monitoring and Information System

WP = Workpackage

w.r.t. = with respect to

YOY = year-on-year

3 Introduction

The CAMERA Performance Framework (PF) was developed at the beginning of the project in 2017 and finalised in 2018 (Paul et al., 2018). The framework addresses 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. It 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) (see Figure 1). The framework is the foundation for the CAMERA project and for the algorithm developed for assessing mobility initiatives.

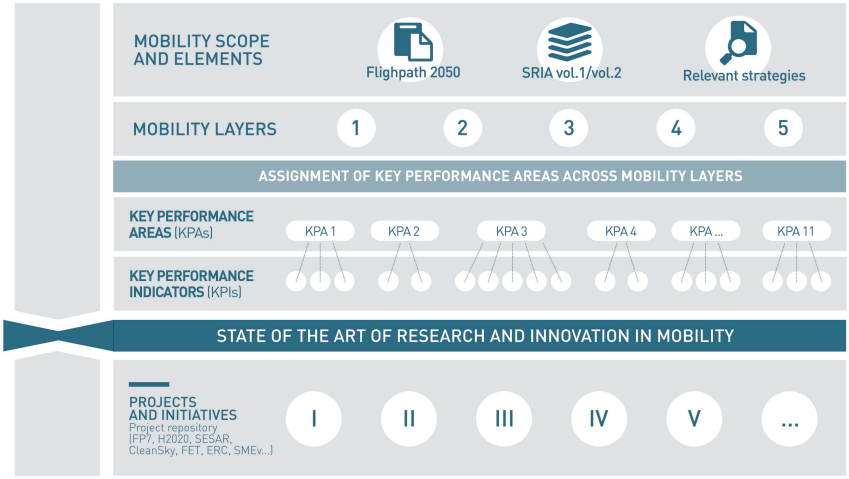


Figure 1: Approach for developing and applying the CAMERA Performance Framework in the project.

This Deliverable D2.2 - *Implementation of the Performance Framework* - covers the high-level details of WP2 tasks execution during CAMERA. In the first section, the CAMERA PF with its five layers, key performance areas (KPAs) and key performance indicators (KPIs) is presented. Next, it is elaborated how the PF was implemented during the project. It is also described how the project repository was established and updated. The outcomes as such (repositories, databases, modelling results etc.) are reported in the Mobility Reports 1 to 4. Further, it is shown how the PF was used beyond the CAMERA project for additional research purposes and disseminations, such as academic journal papers.

Further, this deliverable reviews strategic documents and mobility agendas published after the development of the initial PF. These inputs are used to present updates to the current version. In short, the revision is mainly driven by creating a more sustainable, digital, inclusive and passenger-centric future mobility system within Europe. The Covid-19 pandemic will influence the path towards tackling these goals in the coming years.

Finally, the deliverable provides some lessons learnt and improvements done to the D2.1 methodology before its conclusion.

4 The CAMERA Performance Framework

European countries need to address the numerous and pressing challenges that hinder the full realisation of the European vision for future mobility: that it should be sustainable, digital, multimodal, highly efficient, and climate-neutral. Aviation plays a lead role in this vision, as growth in demand for air transport services is expected to increase again in the coming years. Understanding the many challenges the European transport system faces today, and will face in the future, and turning these into measurable objectives is part of several transport research agendas.

In the CAMERA project, these diverse challenges and their related objectives are combined and translated into CAMERA mobility layers: five different layers that are outlined in further detail below. Although CAMERA puts air transport at the centre of the mobility system, it takes a passenger viewpoint by considering the entire door-to-door journey. For these passengers, air travel is only one leg of a journey that also includes the trips to and from the airports, and navigating the processes within the terminals. Often these segments constitute the longest part of the journey. Because CAMERA does not just concentrate on one leg of the passenger's journey, it can pursue a wider mobility scope by considering the interaction between different transport modes, or the performance of the overall system. This approach is reflected in the definition of the CAMERA mobility layer challenges, and consequently in the selection of the research initiatives considered for analysis later on.

The following section briefly reiterates the five CAMERA mobility layer challenges and their main goals.

4.1 Mobility layer challenges

4.1.1 Layer 1: Creating a personalised and seamless mobility system for everyone

21st century travellers differ in many ways, with diverse demands and requirements of the European mobility system. This system should in future be inclusive and provide intermodal solutions for all types of users. The age of digital transformation, artificial intelligence, and data literacy means that customers' demands will be even more diversified. Upcoming generations of travellers will be more empowered through technological advances and higher data availability. This imposes requirements on the air transport system such as various self-service facilities at airports, information on disruptions and delays along the entire journey, with the ability to proactively react to potential hiccoughs. Similarly, mobility providers also realise that they need to provide more options to allow travellers to manage and customise their travel arrangements at their own pace. Personalised travel arrangements are one of the biggest drivers of customer demand in the age of big data. In an effort to create an easy and user-friendly transport system, single ticketing that incorporates all modes of transport could further increase service quality and seamlessness for passengers. All the improvements mentioned above must also keep safety, security, and environment-friendliness in mind.

The realisation that each customer has unique travel needs has led to increased research into different customer profiles and their related expectations, which include different aspects of the passenger experience. Mobility providers have realised that these have an impact on mobility choices that passengers make. In the end, their passengers are the users of the system and shape the demand for mobility.

With these developments in mind, the CAMERA project adopts a passenger-centred perspective. This influences the definition of indicators, selection of mobility-relevant projects and other modelling activities connected to this layer. However, the passenger is not the only concern. The socio-political acceptance of mobility is another important aspect that must be considered, an example being the impact of transport projects on the environment and on ordinary citizens. Nor should the business aspect be forgotten; incentives for innovation in new technologies, mobility products, concepts, and services and hence the potential for market penetration, must be taken into account.

4.1.2 Layer 2: Improving the overall performance of the mobility system

The different steps of a passenger's journey cannot be enhanced or optimised in isolation; a holistic approach that looks at the performance of the overall transport system is required. Flightpath 2050 goals explicitly address the target of 90% of intra-Europe journeys involving an air leg being potentially achievable in under four hours door-to-door (4HD2D) by 2050 (European Commission, 2011). To describe the current state of the mobility system in Europe and its progress towards the targets envisaged in Flightpath 2050, it is necessary to capture crucial information on the door-to-door journey, including economic and environmental considerations, as performance indicators in a more fact-based discussion of the CAMERA project. This approach can help to drive innovation in transport and the optimisation of overall mobility performance, such as accessibility, interoperability, and punctuality. These metrics are valuable for managing the travel process by monitoring and forecasting the flows within the system. This framework also provides benchmarks for the evaluation of the impact of new technologies and services.

4.1.3 Layer 3: Improving the resilience and re-configuration of the mobility system

Commercial aviation is subject to a number of events that can disrupt the air traffic management system such as bad weather, an external attack, a crisis, or an air traffic control (ATC) strike. If the resilience of the air transport system falls short, this might significantly delay flights, resulting in cascading effects across the overall network and passengers' entire journeys. The reaction of the overall system to these events determines the degree to which seamless and efficient operations can continue and what additional costs are incurred. Improving the resilience of the European transport system is an ambitious goal envisaged by Flightpath 2050, including the target that all flights should arrive "*within 1 minute of the planned arrival time, regardless of weather conditions*" (European Commission, 2011, p. 11). Additionally, the transport system should be capable of automatically and dynamically re-configuring the journey within the network to meet the needs of the traveller. The CAMERA project focuses on identifying, understanding and analysing the research initiatives that work towards meeting these goals, including minimising travel delay or re-configuring itineraries.

4.1.4 Layer 4: Providing safe and efficient air traffic management services

Pre-Covid, the increase in the number of flights over the years has put enormous pressure on the capacity of the air traffic system to handle them. This frequently resulted in delays to scheduled flights. Future challenges include the provision of services that enable the safe and efficient incorporation of "*at least 25 million flights a year of all types of* vehicle" (European Commission, 2011, p. 11) into the overall system while also reducing the environmental impact. Hence, reducing and handling congestion is one of the major challenges to be addressed. CAMERA's analysis of the research landscape includes looking at progress towards reducing delays, the implementation of network congestion management and recovery mechanisms, and the establishment of a system that accommodates all vehicle missions and aerial applications.

4.1.5 Layer 5: Designing and implementing an integrated, intermodal transport system

The efficient integration of different transport modes and the provision of air transport interface nodes is crucial to ensuring progress towards a seamless European mobility system that meets both passenger needs and additional capacity requirements as soon as pre-Covid-19 levels are reached again. As a result, European mobility goals, as outlined in Flightpath 2050, focus on the optimisation of services and processes within these nodes, and on the integration of air transport infrastructure with other modes. The goal, therefore, is to achieve an intermodal network and related processes. This also includes the capability of integrating new (air) mobility concepts and technologies. CAMERA investigates the progress towards increased interoperability across transport modes. This is considered significant in reducing travel time as well as reducing unnecessary inconvenience for passengers. Another challenge aims to ensure access and equity for different user groups, as already outlined within Layer 1. This can also include monitoring the availability of barrier-free access possibilities or the availability of different means of accomplishing a redundant presentation of essential information across all transport modes

4.2 CAMERA's Key Performance Areas

In order to measure the status of the five layers and translate them into a metric, CAMERA developed eleven KPAs as part of the CAMERA Performance Framework. The KPA names were taken from ICAO's (International Civil Aviation Organization) *Manual on Global Performance of the Air Navigation System* (ICAO, 2005; ICAO, 2009) (except 'digitalisation and information').

The KPA **Digitalisation and information** refers to providing real-time and high quality travel information and connectivity to passengers before, after and during their journeys. Digital transformation ('digit(al)isation') throughout the travel chain allows travel time to be used more flexibly, which supports passengers to make better choices regarding how to use their in-vehicle time, be this for work or leisure, and thus increases their overall utility. **Safety** refers to technical and operational measures taken to reduce accidents and fatalities, create a safe transport system, and ensure a high perception of safety among passengers. **Interoperability** refers to the concept of intermodal integration, data and information sharing across transport modes, and the alignment of respective infrastructure to facilitate passengers' door-to-door journeys. **Access and equity** refers to seamless, multimodal and inclusive surface transport to and from the airport as part of the entire door-to-door journey, including public transport, private vehicles,

and novel and innovative transport concepts. **Security** refers to Europe-wide security standards that affect passengers and transport providers and are necessary for keeping the overall transport system safe from attacks. This includes data protection laws across mobility providers. **Environment** refers to creating an environmentally friendly mobility and air transport system by reducing greenhouse gas and other emissions, and incentivising passengers and mobility providers to convert to environmentally friendly technologies and solutions, as well as increasing operational efficiency. **Flexibility** refers to the possibility of passengers using different modes on-demand for a given route according to the personal situation - in line with the Mobility-as-a-Service (MaaS) concept - and to creating a resilient transport system to react to disturbances along the entire door-to-door journey. **Predictability** refers to the ability to predict possible disturbances and consequences, short or long term, so that recovery actions can be promptly prepared to ensure that the different means of transport are on time, and to allow enhanced travel planning that reduces actual travel times. **Capacity** refers to meeting passenger requirements at the required time either through providing sufficient transport possibilities or through using available possibilities efficiently, as well as being able to integrate new or amended mobility solutions efficiently. The KPA **(Operational) efficiency** refers to creating an optimised transport system in terms of costs, emissions and overall travel time along the entire door-to-door journey. **Cost effectiveness** refers to air traffic control (ATM)-related costs and to passenger-orientated costs, whether the passengers are the ones causing (additional) costs to other airspace users or the ones suffering the costs. Cost effectiveness also includes the effort for creating a seamless and resilient mobility system on the supply side along the entire door-to-door journey.

As can be seen in Figure 2, the same KPAs are considered in several mobility layers. Further, a set of KPIs is defined within each mobility layer for the different KPAs. These indicators enable the measurement of progress towards European mobility goals. Indicators are generally formulated in a way that allows a quantitative assessment using data (subject to data availability) by comparing the current value of a KPI against the target value, thus providing insight into further research and development needs.

An extensive discussion of the layers and the development of the CAMERA Performance Framework is provided in the project's Deliverable 2.1 *Establishment of Performance Framework* (Paul et al., 2018).

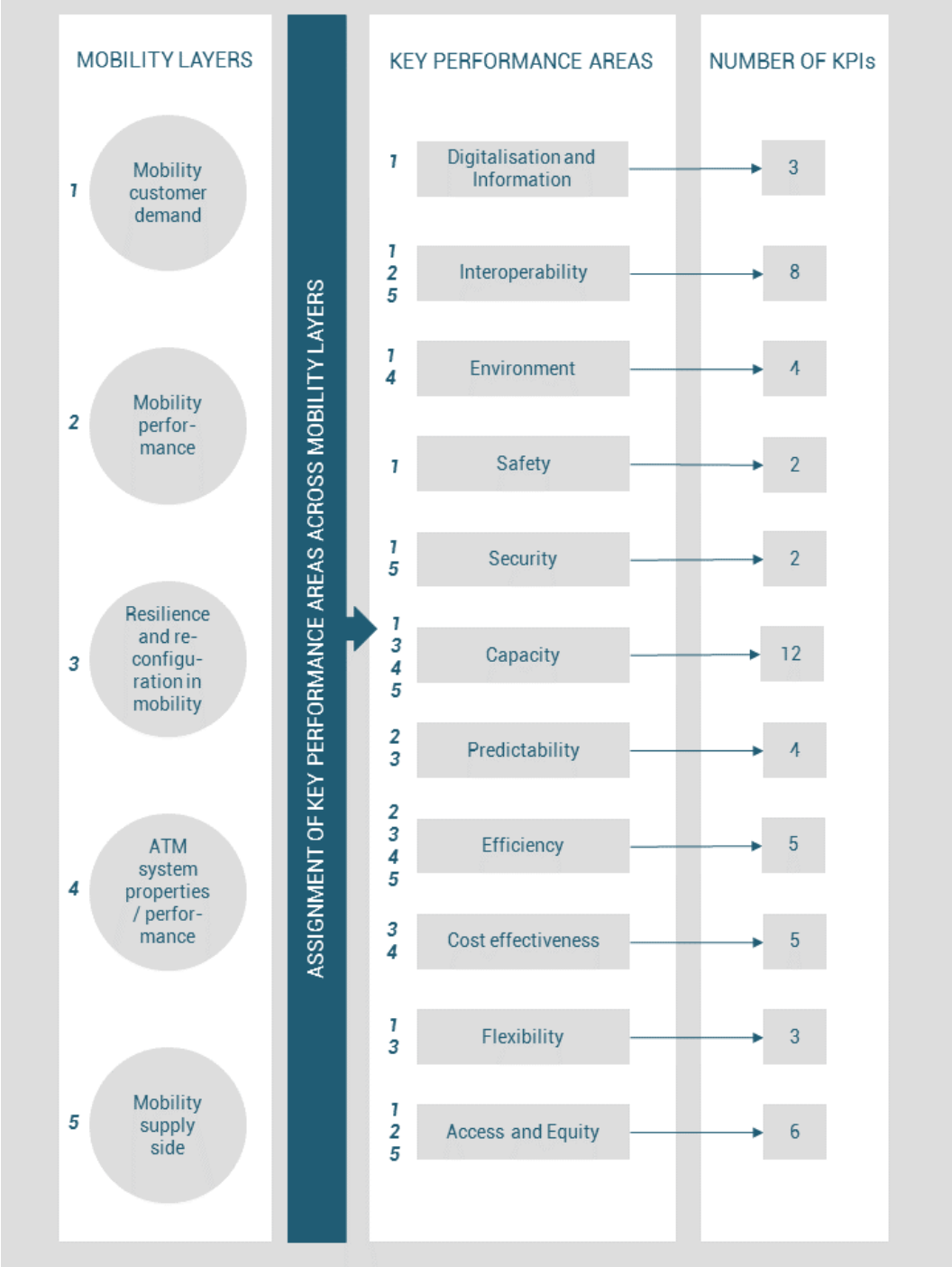


Figure 2: Initial CAMERA Performance Framework as developed in 2018 (Paul et al. 2018).

5 Implementation of the CAMERA Performance Framework

5.1 Implementation in WP3 Models

5.1.1 Establishing a project repository and its updates

Using the Community Research and Development Information Service (CORDIS) database (European Commission, 2021a), a project repository was established. The first step of the CAMERA assessment was to identify all projects funded under the FP7 and H2020 programmes relevant to improving mobility in Europe. To ensure that all meaningful projects are considered, automatic filtering models have been developed and run over the whole database of projects funded under these programmes regardless of their original topic. This FP7 and H2020 project information is freely available at the EU Open Data Portal, which contains all data included in CORDIS such as title, funding programme, project abstract, EC contribution, partners and coordinator.

The full dataset contains over 40,000 projects on very diverse topics, most of them not in the scope of mobility research. In order to narrow the analysis specifically to the projects relevant for CAMERA, the consortium needed to filter out the irrelevant (non-mobility) projects. The dataset provides a field with a code, which classifies each project into a predefined topic. Even though those codes can be considered a good orientating point for classifying the projects, they are still too generic and cannot really shed light onto a definitive topic researched in each project. However, each dataset also contains a number of textual data fields, such as the title of the project, a short summary (abstract), final results summary, etc.; which proved to be very useful for better understanding the topic of each project and classifying them according to their research theme. By utilising the textual information written by the project authors themselves and Natural Language Processing (NLP) algorithms able to digest that information in an automatic manner, we go beyond the classification provided by topic codes in the database.

As a first step, for the filtering of the 40,000 projects, the consortium relied on NLP algorithms (i.e., text mining). Without algorithmic tools, relying on the traditional expert-based approach, this task would have been highly resource consuming. The NLP algorithms have seen a large upsurge in efficiency and accuracy in the past several decades and are often able to differentiate between topics at levels closely comparable to human interpretation.

For the Mobility Report 1 (Biscotto et al., 2019), an initial dataset of 158 projects was retrieved and taken as a basis for a first analysis, which aimed to test the methodology. In the course of CAMERA, the project repository was updated. Expert workshops helped the consortium to redefine the project selection. Finally, 926 projects funded by FP7 and H2020, and whose data were retrieved from the CORDIS database, were found to be in scope. These projects have either already been completed or are still in progress. Results are reported in Mobility Report 2 to 4 (Biscotto et al., 2019; Biscotto et al., 2021a; Biscotto et al., 2021b; Biscotto et al., 2021c).

5.1.2 *Matching project repository with the CAMERA Performance Framework*

Applying this database, the built-up project repository was matched with the CAMERA Performance Framework.

First, starting from the content of projects' textual descriptions (CAMERA Project Repository), latent Dirichlet allocation (LDA) analyses were carried out to explore underlying content patterns in those texts to group the most similar documents together. Thus, in addition to obtaining a set of mobility projects used for this analysis, the second result of this topic modelling technique was the grouping of the selected projects into nine automatically created groups, i.e., topics with each being described by a set of keywords. We refer to a group of projects belonging to the same topic as a word cloud (see Figure 3). Each topic is characterised by a number of keywords extracted from the analysis.

Figure 3: Mobility research topics developed in CAMERA (Biscotto et al. 2021a).

Text mining techniques have also been applied in Mobility Report 1 to analyse the impact of R&I initiatives on the defined mobility challenges within CAMERA, by performing a comparison of the project summaries across the five layers defined in the CAMERA Performance Framework. In order for the text mining algorithms to better understand each layer of mobility challenges, the CAMERA Performance Framework was extended with additional textual data describing the challenges. This initial analysis resulted in a heat map, which demonstrates the similarity of results between mobility projects and layers of the CAMERA Performance Framework. By this approach, which has been further refined in the consecutive Mobility Reports, a comprehensive picture of whether all mobility layers are equally addressed by the research landscape or whether focus is placed on a particular layer can be obtained. It is also possible to identify whether a project has a very narrow focus, i.e. only referring to a particular mobility layer or key performance indicator (KPI), or conversely, if it contains a broad scope in terms of research focus.

Both the clustering of projects into topic clouds as well as the matching of these with the CAMERA mobility layers has been advanced in Mobility Report 2 by:

- Database improvements
- Evolution of the data mining methodology
- Wider concept of mobility relevance, consultation of mobility experts regarding the selection criteria of mobility relevant projects
- More robust validation of the automated AI methodology
- More in-depth analysis of projects relevant to mobility

This well advanced approach has been applied in Mobility Report 3 to show, for example, how the research topic focus of the projects has moved over time. Moreover, the results of the quantitative part of the analysis performed in CAMERA are compared with those of the qualitative analysis. In this regard, CAMERA performed a series of expert consultations, workshops and meetings to gather insights on the state of mobility research in Europe. CAMERA therefore introduces a human in the loop and creates an iterative analytical approach as an interplay between human experts and algorithms, capable of extracting information from large datasets that is, at times, very difficult (or even impossible) to identify through manual inspection alone.

5.1.3 Usage of CAMERA Performance Framework in mobility research models

The CAMERA Performance Framework is a cornerstone for many models developed in the scope of WP3: Mobility research assessment and modelling. Starting with the model that filters out mobility irrelevant projects, the knowledge gathered in the CAMERA Performance Framework has been incorporated to guide that model (it is a semi-supervised algorithm) so to help it kick-start the selection of the projects, as well as in the validation and verification of the results where the selected projects were validated by human experts (consortium members plus the participants in the 2nd CAMERA workshop who worked on a sample of projects), whose verification activities were guided by the indicators defined in the CAMERA Performance Framework.

In the domain of modelling exercises performed in CAMERA, the Performance Framework had the biggest use and impact when it comes to models that were built and analyses that were performed to assess the projects against the defined mobility layers and KPAs. The textual mining based analyses employed the CAMERA Performance Framework and delivered a number of various metrics, many of them from the domain of textual mining - such as various semantic similarity metrics, and consequently data visualisations (such as heat maps described above). The full list of defined KPIs, across eleven defined KPAs, has been used to deliver the information retrieval model that ranks the analysed mobility research initiatives by importance **for each KPA according to its definition in the CAMERA Performance Framework**. In other words, ranking of the projects per relevance for a particular KPA is done primarily against the KPA as described through its indicators and objectives in the Performance Framework, additionally enriched by keywords and indicators defined in consultation with other stakeholders and advisory board members, and thus the CAMERA Performance Framework presents the foundation for that model. That means that, should the definition of a KPA change, for example, the relevance of the projects for that KPA and their ranking can be expected to change as well. The results of this model and additional insights related to it

can be consulted in Mobility Report 4 (to be published soon) and at the accompanying CAMERA Dashboard (CAMERA, 2021a).

We instruct the reader to refer to more details regarding modelling activities in CAMERA in the upcoming Deliverable 3.2 *Mobility research assessment and modelling: implementation*, where the modelling exercises and accompanying analyses, including the usage of the CAMERA Performance Framework in the models, are explained in more detail.

5.2 Usage for Dissemination Purposes

The CAMERA Performance Framework is used beyond the project for additional research purposes and disseminations. During the PF development phase in 2018, 17 subject matter experts were interviewed to gain their inputs regarding future mobility challenges in 2035. The interview results were not just used to formulate the layers, KPAs and KPIs (in particular used for Layer 1 "creating a personalised and seamless mobility system for everyone") but also carried forward in an extended Delphi-based scenario study. Within this research endeavour, 38 mobility experts along the door-to-door air travel chain were surveyed in two rounds on the assessment of 17 trend hypotheses (see Figure 4), which are partly based on the CAMERA project. Results of the Delphi study confirm personalisation and digitalisation as main drivers of further European mobility. Further, three trend scenarios are developed and discussed: (1) personalised door-to-door travel, (2) integrated door-to-door travel, and (3) the game changer (depicted in Figure 5). Results were presented at the Agency Research Team (ART) workshop on passenger-centred mobility by EUROCONTROL in 2021. For more information on the study, please also see the published journal papers Kluge et al. (2020) and Schmalz et al. (2021).

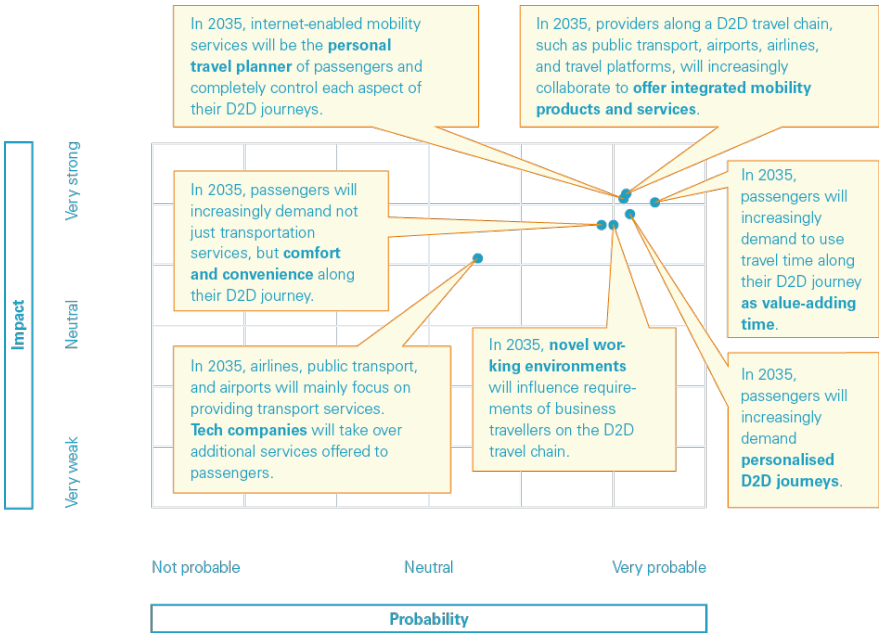
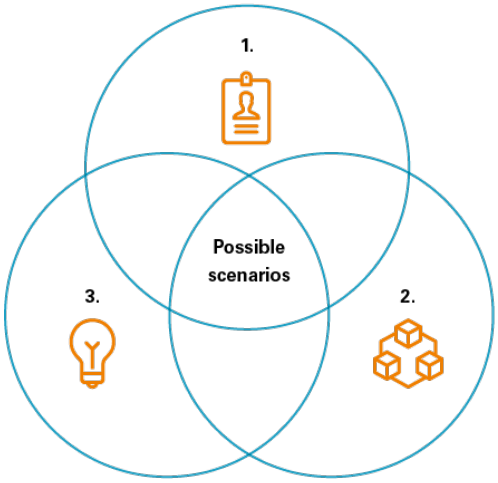


Figure 4: Confirmed trend hypotheses (adapted from: Kluge et al. (2020)).



1. **Personalised travel**
   - » Digital-controlled travel for increasing passengers' experience
   - » High personalisation focusing on customer needs, while also creating comfort and convenience

2. **Integrated travel**
   - » Collaboration between providers aiming to offer integrated, intermodal, and seamless transport services
   - » Creating valuable travel time for passengers
   - » Focusing less on differentiated products from individual mobility providers

3. **Game changer**
   - » Monetisation of the aircraft cabin by technology companies (e.g. in-flight entertainment, catering, in-flight shopping)
   - » Disrupting the supply side and changing revenue streams for established mobility companies, which become pure transport providers from A to B

Figure 5: Three trend scenarios on the possible future of D2D air travel (adapted from: Kluge et al. (2020)).

Further, the identification and application of KPAs as well as respective KPIs provides valuable input for different European projects as well as research initiatives. The H2020-SESAR Modus project (2021), for example, explores the connection between ATM/ air transport and other transport modes, and for this purpose the indicators developed in CAMERA prove to be a useful starting point. In the Modus project, passenger mobility metrics, as they are also employed in CAMERA, enable quantitative insights into the performance of the European transport, such as rail and air capacities or travel times from door to door. Furthermore, there are synergies with the H2020-SESAR TRANSIT project (2021), which focuses on developing multimodal KPIs to evaluate the quality and efficiency of the door-to-door passenger journey.

The results from the CAMERA project, as outlined in the Mobility Reports, also provide valuable input for both the assessment of current mobility goals as well as the identification of important fields of research. In regard to this, the CAMERA Performance Framework is an approach to evaluate the goals outlined in the Strategic Research and Innovation Agenda (SRIA) of the Advisory Council of Aviation Research in Europe (ACARE), or the Strategic Transport Research and Innovation Agenda (STRIA).

In light of the recently published Sustainable and Smart Mobility Strategy (European Commission, 2020) the CAMERA Performance Framework and the related assessment can contribute to evaluating these strategy's objectives in a comprehensive way, especially in regard to research activities and topics taking place in the air transport sector. For example, within this strategy it is outlined that seamless multimodality enabled by digital solutions is vital in urban and sub-urban areas, and that there is increasing demand for new and innovative solutions, with various transport services being integrated into a service accessible on demand. The identification of research topics within CAMERA, including *Green Urban Technologies* or *Novel Concepts in Mobility,* may help to understand in more detail which of the areas discussed in the Sustainable and Smart Mobility Strategy are already being addressed in research and can therefore contribute to meeting the milestones and objectives formulated within this strategy.

6 Update of the CAMERA Performance Framework

6.1 New Mobility Documents

The CAMERA Performance Framework was developed in 2017 and finalised in 2018. Therefore, the published framework might not include some of the latest emerging trends and recently published key documents. In the course of the CAMERA project, the list of KPIs has been further developed, also due to the publication of new strategic documents such as The European Green Deal (European Commission, 2019a) or the Sustainable and Smart Mobility Strategy by the European Commission (European Commission, 2020). Strategic documents from other transport modes, such as the rail or waterborne sector, and white papers are also reviewed. An overview of essential work published after the initial PF development is depicted in Table 1. Further, experts' input from the CAMERA workshop conducted in July 2021, in which parts of the CAMERA Performance Framework were discussed and developed further, are also considered. Other documents, such as an updated ACARE SRIA, were not released until the submission date of this deliverable and are not included.

Table 1: Overview European mobility strategies (adapted from (Paul et al. 2021)).

Strategic EU Documents			
Authors / Institute	**Year**	**Title**	**Short Description**
European Commission (EC)	2019	Trans-European Transport Network (TEN-T) Review	This work provides a **review on the Trans-European Transport Network (TEN-T) policy**, which supports symbolises connectivity and accessibility for all regions of the Union. Through several revisions, the policy has coped with growing transport demand, geo-political developments (several EU enlargements) and evolving transport policy challenges (e.g. liberalisation, standardisation, technological innovation).
EC	2019	The European Green Deal	The European Green Deal provides an **action plan** to boost the efficient use of resources by moving to a **clean, circular economy, to restore biodiversity and cut pollution**. The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition. The document is the **basis for other strategic documents**, such as for the Sustainable and Smart Mobility Strategy or the SESAR SRIA.
EC	2020	Sustainable and Smart Mobility Strategy	This strategy lays the foundation for how the EU transport system can achieve its green and digital transformation and become more resilient to future crises. As outlined in the European Green Deal, the result will be a **90% cut in emissions by 2050, delivered by a smart, competitive, safe, accessible and affordable transport system.**
EC	2021	EC welcomes adoption of new rail passenger rights	The **new rail passenger rights framework** follows a 2017 Commission proposal and will apply as of 6 June 2023. It includes a new obligation for carriers qualifying as a 'sole undertaking' to offer their international, long-distance domestic and regional rail services as a through-ticket.

EC	2021	Fit for 55	Fit for 55 is a package of proposals in which the European Commission presents the legislative tools to **deliver on the targets agreed in the European Climate Law** and fundamentally transform the European economy and society for a **fair, green and prosperous future.**

SRIAs & Action Plans

Authors / Institute	Year	Title	Short Description
SESAR Joint Undertaking	2020	SESAR SRIA	This Strategic Research and Innovation Agenda (SRIA) details the **research and innovation roadmaps to achieve the Digital European Sky**, matching the ambitions of the "European Green Deal" and the "Europe fit for the digital age" initiative.
Shift2Rail	2020	Multi-annual Action Plan	The Shift2Rail (S2R) Action Plan provides a high-level view of what needs to be done It sets the **framework for the research and innovation (R&I) activities to be performed** as part of and beyond the S2R Programme (1) and the deployment activities to be carried out by all operational stakeholders, coordinated to achieve a Single European Rail Area.
WATERBORNE Technology Platform	2020	SRIA (draft version)	The waterborne transport sector is committed to develop and demonstrate disruptive **solutions to address the challenges of climate change, air pollution and the degradation of the world's oceans.** The new Strategic Research and Innovation Agenda (SRIA) outlines the technical pillars to tackle the aforementioned challenges.
NLR, Royal Netherlands Aerospace Center & SEO Amsterdam Economics	2021	Destination2050	Destination2050 outlines a possible **route toward net-zero European aviation** by the combination of four key measurements: 1) Improvements in aircraft and engine technologies; 2) Increased usage of sustainable aviation fuels (SAF); 3) Implementing economic measures; 4) Improving operations and ATM
EASA	2020	AI Roadmap	The purpose of the European Union Aviation Safety Agency (EASA) AI Roadmap is to **discuss the implication of AI on the aviation sector and identify high-level objectives to be met and actions** to be taken to respond to pressing questions.

Analytical Reports

Authors / Institute	Year	Title	Short Description
EASA, EEA & EUROCONTROL	2019	European Aviation Environmental Report	This report provides an **assessment** of the **environmental performance** of the **aviation sector**. It is the second edition and provides some updates to the report from 2016.
SLOCAT	2021	Transport and Climate Change Global Status Report	The Partnership on Sustainable, Low Carbon Transport (SLOCAT) Transport and Climate Change Global Status Report tells the **global and regional stories of where we are and where we need to get to urgently on climate action in the transport sector.** With contributions from more than 150 world-class experts and organisations, it is a **one-stop shop for the latest available data,** targets and developments on transport demand, emissions, policies and measures.

EEA	2020	Transport and environment report 2050 train or plane?	The report by the European Environment Agency (EEA) **assesses the value of travel by train and plane.** Rail travel is the best and most sensible mode of travel, apart from walking or cycling. Aviation's emission impacts are much higher on a passenger-kilometre basis. Travel by a petrol or diesel-powered car can also be more harmful.
TRIMIS	2021	Rail transport research and innovation in Europe	This report **provides a comprehensive analysis of R&I initiatives in Europe.** The assessment follows a structured methodology developed by the European Commission's Transport Research and Information Monitoring and Information System (TRIMIS). The report critically addresses research by thematic area and technology, highlighting recent developments and future needs.

White Papers & Others

Authors / Institute	Year	Title	Short Description
EUROCONTROL	2020	FLY AI report	The report aims to **demystify AI, help its uptake in aviation and advance understanding of its potential** for example in areas such as reducing human workload, driving the development of new ATM/U-Space services, or increasing safety and cyber resilience. It includes a Fly Action Plan which sets out the **practical actions that could be taken to accelerate the development of AI in European aviation and ATM.**
World Economic Forum & IEA's Sustainable Development Scenario	2020	Cars, planes, trains: where do transport CO_2 emissions come from?	This article provides an overview and discussion of **emissions across multiple transport modes**.
EUROCONTROL (Aviation Sustainability Unit)	2021	Think paper - Plane and train: Getting the balance right	The paper **reviews the latest literature comparing air and rail sustainability**, assesses whether shifting from air to rail across Europe is a realistic option, and identifies areas where air and rail could be complementary, rather than mutually exclusive.
CAMERA	2021	Workshop "Exploring the Main Mobility Research Gaps in Europe" (17.7.2021)	The goal of the CAMERA **workshop** was to present project results and to obtain experts' feedback. This so-called "human in the loop" exercise helped to steer the model outcome, to include experts' input and to **improve the CAMERA algorithm and overall methodology**. Within the breakout sessions, feedback on the CAMERA Performance Framework was also obtained.

6.2 Update of the CAMERA Performance Framework

Following the current version of the PF as presented at the beginning of this deliverable, the following updates are proposed as additional remarks. These updates are driven by several key priorities and enablers. As stated in the European Green Deal, a more sustainable future is the main objective and the key challenge of this generation. In fact, "*(a)ll EU actions and policies will have to contribute to the European Green Deal objectives*" (European Commission, 2019a, p. 3). Digitalisation and artificial intelligence (AI)

are enablers to support this effort but also to improve the overall transport system and increase passengers' experiences. A sufficient data basis, also shared between mobility providers, and trustworthiness are prerequisites for a successful AI deployment (EASA, 2020; EUROCONTROL, 2020). The Covid-19 pandemic will influence the path towards reaching these goals in the coming years (SESAR Joint Undertaking, 2020). Finally, within all actions, it is essential to put the passengers first and create an affordable and inclusive mobility system (European Commission, 2019a; European Commission, 2020).

In the current PF version, the KPA **Environment** focuses on CO_2 emissions. As critically noted by the experts in the CAMERA workshop (CAMERA, 2021b), environmental KPIs should not just focus more on definitive actions to reduce CO_2 emissions, as for instance outlined by Destination2050 (NLR & SEO, 2021), but also on the reduction of non-CO_2 emissions (CAMERA, 2021b). The impact of non-CO_2 emissions is already supported by recently published academic work (Lee et al., 2021). This PF update proposes first KPIs to also measure the non-CO_2 emissions, the service life of vehicles, and the establishment of a sustainable supply chain, for instance. Given the intermodal scope of the CAMERA project, one should also consider emissions from all transport modes, not just aviation (European Environment Agency, 2020; Ritchie, 2020).

The KPA **Digitalisation & Information**[1] should include KPIs that support the digital transition of European mobility, such as to push data technologies, AI, and the development of a human-centric AI trustworthiness framework (EASA, 2020; EUROCONTROL, 2020; European Commission, 2020). Digitalisation should be used to support the transition towards sustainable transport (green digital) (European Commission, 2020; European Commission, 2021b). Experts from the CAMERA workshop also demand from this KPA to truly support passengers along the entire D2D air travel chain, such as with timely access to travel information and real-time updates for a variety of consumer devices (CAMERA, 2021b). It seems essential to distinguish more between keeping travellers entertained and being informed (CAMERA, 2021b). Further, indicators do not directly reflect all passenger types but differentiations might be necessary. For instance, entertainment might mean something completely different for families and younger travellers.

The KPA **Capacity** should broaden its scope towards creating an infrastructure to support the green and digital transformation towards sustainability and inclusive mobility within Europe (European Commission, 2020; SESAR Joint Undertaking, 2020; SLOCAT, 2021). For instance, to support the decarbonisation of ground mobility, and in particular access and egress modes to and from the airport as part of the travel chain, a widely developed, publicly available and fully functioning network of recharging and refuelling stations is required. To create an inclusive European transport system, creating a barrier-free infrastructure along the entire travel chain should become a priority.

The KPA **Flexibility** should capture the ability for passengers to change travel plans (CAMERA, 2021b) - for instance to avoid crowded places during the Covid-19 induced crisis (Gkoumas et al., 2021) - as well as the total extension to the D2D journey time because of reconfigurations (CAMERA, 2021b). Flexibility should improve the overall passenger satisfaction (CAMERA, 2021b; NLR & SEO, 2021), such as for multimodal travel (SESAR Joint Undertaking, 2020). However, a passenger's satisfaction with the flexibility of

[1] *Please note: the CAMERA consortium adapted this KPA. It is the only one that differs from the ICAO standard set.*

their journey is not the same as their satisfaction with the IT available. The IT is not an enabler of the flexibility; it is the facilitator. Some sort of passenger satisfaction indicator should be included in an updated PF version but passenger satisfaction is a qualitative indicator that requires surveys with a high sample size, hence, an automatically quantifiable indicator was not found. Although surveys are the only direct source, they are vital drivers of understanding broader utility dimensions (such as 'comfort'), which drive market share.

Predictability is more than just measuring delays. Recoverability is a key effort that should be considered: it is essential to explore where and why a delay happened and to include missed connections and cancellations along the travel chain (CAMERA, 2021b). Improvements in the area of predictability can also be made with enhanced predictions and preparations for the impact of climate change (EUROCONTROL Aviation Sustainability Unit, 2021) as well as enhanced skills of human expertise to the interpretation of forecasts and the derivation of actions (CAMERA, 2021b).

Next to fatalities, the KPA **Safety** should include KPIs measuring incidents and accidents along the entire D2D travel chain (CAMERA, 2021b). Data sharing and AI-deployment can maintain, or even improve, safety levels (SESAR Joint Undertaking, 2020).

To be inclusive, **Access & equity** should include surface transport to and from the airports that also covers connections of remote regions within Europe (European Commission, 2019b; European Commission, 2020). Airports should develop into multimodal hubs, offering seamless and stress-free connection transport (European Environment Agency, 2020).

Following this, please note that intermodal integration at airports is already covered within the KPA **Interoperability**. However, the KPA should focus more on the implementation of collaborative processing across modes (SESAR Joint Undertaking, 2020), pushing towards Mobility as a Service (MaaS) within Europe (European Commission, 2019a; European Commission, 2020; Shift2Rail, 2020). All these actions need to be enabled by overarching regulations setting the framework conditions for the design, implementation and operation.

In line with that, there is ample room to improve the operational reliability within the KPA **Operational Efficiency.** This relates to aviation but to other transport modes too, such as to the railway system. A true multimodal view is needed. The full implementation of the ‘Single European Transport Area’, as proposed in the Sustainable and Smart Mobility Strategy on page 17 (European Commission, 2020), will create a more resilient European transport system and improve connectivity further.

Within an updated PF, **Cost effectiveness** requires a rethinking away from pure economical costs. Passengers need affordable mobility in Europe (European Commission, 2019a). Investments into large-scale deployments and demonstrations of new technologies across sectors need to be done to create a future-oriented mobility system (European Commission, 2019a). Further, external costs should be internalised, such as by implementing the ‘polluter pays’ and ‘user pays’ principles, carbon pricing and infrastructure charging mechanism (European Commission, 2019a).

The high **Security** standards within transport need to be met. In line with CAMERA's multimodal scope, data protection rules should not just be aligned among providers, but also respect passengers' data protection and privacy (European Commission, 2019a). As within other KPAs, AI-based solutions in operations of cybersecurity and non-safety critical operations will provide the possibility to stay cyber-resilient to new technologies and threats (EUROCONTROL, 2020; SESAR Joint Undertaking, 2020).

In fact, given the upper relevance of data usage, data protection, data exchange and harnessing AI-models to improve transport and make mobility smarter (EUROCONTROL, 2020; European Commission, 2020), we propose a new KPA focusing on data and AI-models. Currently, data-related issues are included in the KPA **Digitalisation & information** and data security goals are incorporated in the KPA **Security**. However, "*AI is becoming essential for transport automation in all modes, with digital technologies and components at their care*" (EUROCONTROL Aviation Sustainability Unit, 2021, p. 16). Further, also given the high relevance of personal data and data protection within Europe, such as the General Data Protection Regulation (GDPR) (European Parliament, 2016), especially regarding the data transfer into third countries outside of the European Union (European Commission, 2021d), a KPA focusing on the use of data would be future-oriented and could help European mobility providers to stay in the game. In fact, it might become a challenge to respect European data protection rules while creating a smarter mobility system with providers sharing data among each other.

Based on the high-level goals of new publications and the findings from the CAMERA workshop, this section proposed extensions to the current version of the CAMERA Performance Framework and its defined KPAs. Additional KPIs are proposed and summarised in Table 2. They are a first step into a new version of the PF, however, further review and validations are required to finalise the updated framework.

Table 2: First update of the CAMERA Performance Framework.

KPA	Additions to KPAs based on newly published work	Proposed Indicator
Flexibility	**More flexibility for passengers** • Flexibility should capture the ability to change a travel plan (CAMERA, 2021b) • Intervention degree needed from the passenger to specify modes used for the journey (CAMERA, 2021b) • Total waiting time across the full itinerary needs to be considered and reduced (CAMERA, 2021b), e.g. time spent at the airport (SESAR Joint Undertaking, 2020) **Improving passenger experience** • Implementation of an efficient multimodal disruption management to improve the passenger experience (SESAR Joint Undertaking, 2020) • Passenger satisfaction should also be considered (CAMERA, 2021b; NLR & SEO, 2021; SESAR Joint Undertaking, 2020) • Passengers' protection should be strengthen in case of disruptions (European Commission, 2021c)	= booking effort on demand side (in min.) = total extension to door-to-door (D2D) journey time because of reconfiguration (in min.) = % of passengers actually connected to an app that allows them to use the flexibility offered = multimodal transport options (per itinerary) = ability to change travel plans (time & mode) = number of realistic travel options available for a journey
Predictability	**Advanced predictability** • Human expertise is needed to fully understand the potential within data science projects, e.g. humans can see value of 'forecasting' w.r.t. predictability more than algorithms can (CAMERA, 2021b) • The KPIs need more variability in the distribution (e.g. if travellers are always 15 minutes late, that's predictable) - interesting to look at the tails of the distribution (CAMERA, 2021b)	= maximum delay (80th percentile) of public transport used as access an airport (D2K)* (in min.) (*to adapt current PF indicators) = time of recovery after disturbance = cancellation rate (in %)

KPA	Additions to KPAs based on newly published work	Proposed Indicator
	• Recoverability: not just a question of overall delay, but where did the delay happen (CAMERA, 2021b) • Need to better predict and prepare for the impact of climate change, e.g. delays due to storms (EUROCONTROL Aviation Sustainability Unit, 2021) • Consider discomfort / disutility: also cancellation & missed connection highly disruptive; not just pure delay per se (CAMERA, 2021b)	= missed connections due to delay (no. of denied boarding)
Digitalisation & information (D&I)	**Make the digital transformation happen** • Make the digital transformation of transport a reality: push a network infrastructure, data technologies, AI etc. (EASA, 2020; EUROCONTROL, 2020; European Commission, 2020) • Develop a human-centric AI trustworthiness framework (EASA, 2020) • Next to the KPA **Security**, D&I should also include use of data standards, networks and data sharing infrastructure, and open source tools (CAMERA, 2021b) **Support passengers along D2D travel chain** • Within the KPA on D&I, one needs to distinguish between a) keeping **passengers entertained** vs. b) **being informed** (CAMERA, 2021b) • Timely access to travel information and updates of the entire travel chain (from door to door) (CAMERA, 2021b) • Stability (so passengers know what digital info to expect, when); goes hand-in-hand with high quality of data (CAMERA, 2021b) • Easy access (plug and play) from variety of consumer devices (CAMERA, 2021b) **Digital green** • Use digitalisation to support the transition towards sustainable transport (European Commission, 2020; European Commission, 2021b)	= availability of multimodal data sharing standards (yes/no) = availability of multimodal data sharing infrastructure and open source tools (yes/no) e.g. European Common Mobility Data Space (European Commission, 2020) = no. of providers sharing data and offering joint services (e.g. Rail&Fly) = availability of real time information and updates on entire D2D travel chain (yes/no) = multi-device services (no. of possible devices) = data quality of real-time updates (accuracy of models & computing time)
Environment	• Increase the EU's climate ambition for 2030 & 2050 (European Commission, 2019a) ○ Reducing net greenhouse gas emissions by at least 55% by 2030 (compared to 1990 levels) (European Commission, 2021b) **Reduction of CO_2 emissions** • Boost the uptake of zero-emission vehicles, renewables and low-carbon fuels and related infrastructure; create zero-emission airports (European Commission, 2020) and waterborne transport (WATERBORNE Technology Platform, 2020) • Investment on new technologies to keep increasing aircraft's efficiency and reducing noise, among others (EASA, 2019) • Incentives for more sustainable choices: carbon pricing, taxation, and infrastructure charging, complemented by improved information to users (European Commission, 2020) • Net-zero CO_2 emissions from all flights within and departing from the EU can be achieved by 2050 through joint, coordinated and decisive industry and government efforts. The European aviation industry is committed to reaching this target and contribute to the goals set in the European Green Deal and the Paris Agreement (NLR & SEO, 2021) • Decarbonisation of ground operations as well as access and egress transport (EUROCONTROL Aviation Sustainability Unit, 2021; NLR & SEO, 2021; Ritchie, 2020; SESAR Joint Undertaking, 2020)	= total greenhouse gas emissions (in kt of CO_2 equivalent) = climate change (in temperature change YOY) = NO_x (and other gases) / non-CO_2-emissions = aerosol particles = air pollution = noise levels (in decibels (dB)) = usage of SAF (in % of overall drop ins; blended drop ins; SAF-quotas) = service life of vehicles (in years) = near-ground emissions (Lee et al., 2021)

KPA	Additions to KPAs based on newly published work	Proposed Indicator
	Reduction of non-CO_2 emissions • Climate change impact (contrails, particles, noise and others rather than only CO_2 such as NO_x) (CAMERA, 2021b) • Scale up and increase use of SAF (European Commission, 2019a; European Commission, 2021b; NLR & SEO, 2021) → SAF to use for other modes along the D2D air travel chain, such as airport feeders • Circular economy (in line with sustainable products policy (European Commission, 2019a)), also of vehicles and infrastructure, with effects on local environment (CAMERA, 2021b) • Increasing transparency and visualisation of choices (European Environment Agency, 2020; Gkoumas et al., 2021), also in terms of total cost of ownership for vehicles (SLOCAT, 2021) • Tackle water pollution (WATERBORNE Technology Platform, 2020) • Raw material effects for industrial production (CAMERA, 2021b) • Waste reduction (European Commission, 2019a)	= availability of transparent pax emissions calculator for entire D2D travel chain = sustainable supply chain (in DIN-certificates) = net-zero CO_2 emissions (all flights) until 2050 (NLR & SEO, 2021) = implementation of eco-labeling (Gkoumas et al., 2021)
Safety	• Safety also includes incidents and accidents, along the entire D2D travel chain (CAMERA, 2021b) **Safety and AI** • Automation and increased data sharing enables advanced collision avoidance and separation management (SESAR Joint Undertaking, 2020) • The implementation of automation and AI will be certified to maintain, or even improve, safety levels in a growing air traffic scenario (SESAR Joint Undertaking, 2020) **Safety and humans** • Passengers' safety perception very important but difficult to measure (CAMERA, 2021b) • Importance of human errors over other types of errors was highlighted in order to actually adapt mitigation actions to the existing risks (i.e. focus safety efforts on reducing human errors, support from technology) (CAMERA, 2021b)	= no. of incidents per pax-km = no. of accidents per pax-km = no. of fatalities per accident = no. of D2D injuries per journey = no. of D2D safety related incidents = no. of maintenance errors (all modes) (downtime in min.) = no. of nearmisses (all modes) = human-related accidents (in % of total accidents) = deployment of safety AI-models with high accuracy (<90%)
Access & equity	**Connection of remote regions** • Mobility is available and affordable for all, rural and remote regions are better connected, accessible for persons with reduced mobility and with disabilities (European Commission, 2020) • The comprehensive network should be a Europe-wide transport network ensuring the accessibility and connectivity of all regions in the Union, including the remote, insular and outermost regions (European Commission, 2019b) **Development of multimodal hubs** • The Trans-European Transport Network (TEN-T) Regulation - Regulation (EU) No. 1315/2013 - stipulates that until 2030 the most important core network components, including urban nodes and airports, are expected to have multimodal links, as long as they	= connectivity of rural areas (90% of houses connected to public transport) = establish multimodal hub at every large airport in Europe (100%)

KPA	Additions to KPAs based on newly published work	Proposed Indicator
	are economically viable, environmentally sustainable and feasible (European Environment Agency, 2020)	
Security	**High secured privacy for passengers** • Respect passengers' data protection and privacy rules; high priority towards cyber security (European Commission, 2021d; European Environment Agency, 2020) **Use the full potential of AI** • Rapid uptake of AI-based solutions in operations of cybersecurity and non-safety critical operations (EUROCONTROL, 2020; SESAR Joint Undertaking, 2020) • AI provides the possibility to stay cyber-resilient to new technologies and threats[2] (SESAR Joint Undertaking, 2020)	= meet European protection rules of personal data (100%) = deployment of security AI-models with high accuracy (<90%)
Interoperability	**Collaborative processing across modes** • Optimisation of airport infrastructure use through advanced collaborative operations and planning services (SESAR Joint Undertaking, 2020) • Enable more collaborative decision-making between stakeholders, thus improving predictability and the network performance as a whole (SESAR Joint Undertaking, 2020) **Regulation to ensure level playing field for service providers** • Conducive framework for EU-wide, integrated, multimodal information, ticketing and payment services (overcoming insufficient availability and accessibility of data, sub-optimal cooperation between suppliers and vendors, the absence of digital tickets in some cases, inadequate payment system interoperability, and existence of different licencing and distribution agreements) (European Commission, 2020) **Mobility as a Service** • Push MaaS for multimodal, automated and connected mobility (European Commission, 2019a) • Demand for new and innovative solutions, with various transport services being integrated into a service accessible on demand, following the MaaS concept (European Commission, 2020) • Become the backbone of current and future mobility concepts (e.g. MaaS) and on-demand future logistics (Shift2Rail, 2020) • Customer demand-driven services lead the railway to provide excellent service within the overall mobility chain. Connections between rail and the other modes are seamless, making mode interchange as simple and as efficient as possible. Information is permanently available to make travel safe and efficient along the travel chain, including at stations. All customers and potential customers are connected to mobility services (Shift2Rail, 2020)	= number of phases / legs required to complete a journey = number of modes used to complete a journey
Capacity	**Creating an infrastructure to support the transformation towards green and inclusive mobility** • To support the decarbonisation of access and egress modes, the infrastructure needs to adapt towards providing a sufficient network for public recharging and refuelling for all	= full coverage of hydrogen stations and public recharging points on the last mile (by 2030)

[2] However, this also introduces new threats.

KPA	Additions to KPAs based on newly published work	Proposed Indicator
	modes (European Commission, 2019a; European Commission, 2020; European Commission, 2021b) • Infrastructure needs to be barrier free (European Commission, 2020) • Based on the Covid-19 crisis and need to create a resilient ATM system, accommodate all traffic forecasts in a crisis-adjusted "regulation and growth" scenario, incl. 'recovered' unaccommodated demand (SESAR Joint Undertaking, 2020) **Creating the infrastructure to support the digital transformation** • Benefit from AI-supported optimisation within capacity planning (SESAR Joint Undertaking, 2020) • Establish a federated data foundation and AI-infrastructure (EUROCONTROL, 2020) • Ensure highest level and performance of a digital infrastructure, notable through 5G. Shape future mobility by developing and validating new technologies (European Commission, 2020)	= barrier free mobility infrastructure (≥90%) = forecasts with crisis-adjusted scenarios (yes, no)
(Operational) - Efficiency	**Multimodal operational reliability** • Work towards a fully implementation of the Single European Sky (European Commission, 2019a; NLR & SEO, 2021) • Fully implement the Single European Transport Area to create an more resilient European transport system and improve connectivity further (European Commission, 2020)	= establishment of the Single European Sky and Single European Transport Area (yes, no)
Cost effectiveness	**Transparency across transport modes** • Internalisation of external costs (implementing the 'polluter pays' and 'user pays' principles, carbon pricing and infrastructure charging mechanism) (European Commission, 2020) • Use of automation and optimised machine support to become more cost efficient (SESAR Joint Undertaking, 2020) **Rethinking cost effectiveness** • Providing passengers with affordable mobility (European Commission, 2019a) • Boost investments into large-scale deployments and demonstrations of new technologies across sectors (European Commission, 2019a)	= implementing carbon pricing scheme for all modes (yes/no) = deployment of cost models with high accuracy (<90%) = investment rate into new technology projects (target: 10% of profit)

7 Lessons Learned and Improvements

Within the WP2 tasks executed in CAMERA, several improvements have been made. This section elaborates on some improvements made to the D2.1 methodology and possible lessons learned. The technical outcomes and lessons learned of the CAMERA project will be discussed in the project forthcoming Deliverable 3.2.

7.1 Continuous development

As seen in the last section, during the course of the project, mobility goals and strategies changed within its foci. Hence, one main lesson learned is the need for a continuous advancement of the CAMERA Performance Framework throughout the project. To tackle this issue partly, the CAMERA consortium worked on a deep dive covering pressing issues, such as the key role of the environment in transport research, options for decarbonisation, and the potential of digitalisation within mobility. These deep dives are presented in Mobility Report 4. Such aspects were covered in less detail in the initial CAMERA Performance Framework. Furthermore, this deliverable provides additions to the current version of the CAMERA Performance Framework.

7.2 Human in the loop

The input from mobility experts is an important source in addition to written agendas and strategic documents. Within the development of the CAMERA Performance Framework, 17 semi-structured expert interviews were conducted to support the development of the framework. Furthermore, a CAMERA workshop bringing together experts from industry, academia and relevant projects to discuss the progress towards European mobility goals, and to refine and extend the key performance indicators defined within the CAMERA Performance Framework. To further detect emerging trends throughout the project, the consortium could have conducted additional interviews for keeping the human in the loop. This concept is successfully used in the modelling exercise and the development of the CAMERA algorithm. Saying that, the CAMERA expert workshop in July 2021 focused partly on the update of some KPAs. Results already provided interesting insights and are used for this deliverable. In retrospect, expert input and discussions have provided valuable complementary insight to the project work and results; extending the integration of experts during the course of the project should play a significant role and consultation could also have been extended even more during the CAMERA project.

7.3 Improve measurement of KPIs

In the course of the CAMERA project, it became clear that it might be difficult to measure and quantify the results and success of the KPIs across the projects in the database in detail, but that a rather high-level approach had to be pursued. For a detailed analysis of individual KPIs, one needs lots of data and very comprehensive analyses. Further work and data (such as project deliverables) are therefore necessary to see to what extent the individual KPIs are met. In line with the CAMERA objective - to investigate and assess whether EU research and initiatives are on the right trajectory to reach long-term goals in the (air) mobility sector - a comprehensive assessment of the mobility research landscape was required instead of a detailed evaluation of a specific KPI. In order to obtain this overview an approach was implemented which applied keywords derived from the key performance indicators in order to evaluate the amount and diversity of projects which focus on a particular aspect (represented by a specific KPI). In this manner, CAMERA provides insights to the degree how well European mobility strategies and goals are currently advanced in research.

7.4 Data availability

It would have been beneficial to have access to all project deliverables within the CORDIS database. The lack of easy and seamless access to data - such as deliverables, social media activities and dissemination materials - could, indeed, be improved. This could include digital object identifier (DOI), links to journal papers, and similarly robust links to project websites and other publications. Regarding problems encountered during the analyses and modelling of materials on the CORIDS website (the consortium eventually agreed on focusing only on H2020 and FP7-funded projects for the analysis), it would also be helpful in the future to use a standard and dynamically maintained set of keywords to describe and index the projects, which could indeed use as a basis some of the NLP data reduction results already reported upon in the CAMERA Mobility Reports. Projects could additionally indicate which of the eleven ICAO KPAs were investigated therein.

8 Conclusion

This deliverable provided an overview of the CAMERA Performance Framework, its main elements, its evolution over the course of the project and its application in regard to the assessment of the progress of the European mobility research landscape.

The essential elements of this framework - the mobility layers, key performance areas, and key performance indicators - provide the basis for the evaluation of European mobility research. Building up a project repository and applying advanced text mining methodologies allowed for the investigation of the topics included in the CAMERA Performance Framework and how extensively these have been addressed in FP7 and H2020 projects. The application and advancement of the PF has been enabled by a close interlinkage between algorithmic tools and expert involvement, thus adding value to the overall outcome of the project.

Inevitably, the application and advancement of such a framework is a dynamic process due to new developments and challenges, which have to be incorporated. Therefore, this deliverable also proposes an update to the established framework based on newly released mobility strategies as well as expert input from a CAMERA workshop. Five pillars mainly drive these updates:

1. **Creating a more sustainable future mobility system**
2. **Digitalisation and digital transformation**
3. **Leveraging the full potential of (shared) data and AI-models**
4. **Putting the passenger at the centre**
5. **The possible long-term influence of the Covid-19-induced crisis**

Addressing these aspects in moving forward in evaluating the progress and gaps in regard to European mobility is essential. The CAMERA Performance Framework and its application throughout the project provides a valuable tool and approach for identifying these gaps and progress as well as for better connecting research areas in the future.

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