

CAMERA

COORDINATION AND SUPPORT
ACTION FOR MOBILITY IN EUROPE
Research and Assessment

Please cite as: M. Biscotto, A. J. Cook, I. Gómez, G. Gurtner, P. Hernandez, P. Hullah, U. Kluge, P. López, D. Martínez, C. Muccitelli, A. Paul, D. Valput , "Mobility Report 3", CAMERA, Madrid, Spain, 2021.

MOBILITY REPORT 3



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PREFACE

The CAMERA project started in 2017 with the goal of analysing mobility research in the EU to provide a bird's-eye view of the status of mobility research initiatives launched in the past decade, and to detect obstacles that still lie ahead in the path to achieving the goals outlined in Flightpath2050.

At the turn of the century, the mobility trend in Europe was clear: we live in the age of high, and continuously growing, demand for mobility, the highest recorded in human history. Today, European air transport is experiencing a plethora of challenges regarding its digital transformation, performance, environmental sustainability and its interface with other transport modes; to which we should now add the impact of the Covid-19 pandemic. At the time of the writing this report, the pandemic is still very much ongoing and its impact, both in the medium and long terms, is completely unknown and difficult to predict. It is certain, however, that the pandemic has brought a great deal of uncertainty, restructured the priorities for many players in the transport industry, and shifted the focus from some old problems to the new one of how to rebuild the industry.

While the effects of the pandemic are not in the scope of the CAMERA project and therefore this report, it would be impossible not to even mention it considering the great impact it had on mobility in the year 2020. From the beginning of the 21st century until 2019, we witnessed a continuous increase in demand for commercial aviation. Such growth can be attributed to, among other things, to the growth of low-cost airlines, the expansion of economies and higher living standards, development of more fuel-efficient jets providing more direct routes, and greater urbanisation rates. It is unclear how and for how long the Covid-related crisis (both health and the associated economic crisis) will continue affecting the mobility in the European Union (EU), but we can be sure that it will bring about a number of changes in air travel and its interface with other modes in the years and decades to come. We already see a number of business pushing harder for digital transformation as a way to refresh their business models and not only survive this crisis, but come out of it as stronger and more sustainable organisations. The focus on environmental responsibility and more sustainable travel continues to be strong and one of the main challenges for mobility in the EU in the future. As European aviation is a crucial asset for economic growth and a large wealth generator for the EU, it is of vital importance to identify crucial areas and address the right challenges for ensuring its sustainable development.

The EU designates significant funds for various research areas through framework programmes such as Horizon 2020 (H2020) and FP7. As part of its coordinating activity, the EU is performing investigative actions across these areas to ensure optimal use of funds and that research properly addresses the needs of European citizens. This report is a result of the analysis performed so far in the scope of the CAMERA project that analyses FP7 and H2020 research initiatives that focus on or contribute to the understanding and development of the European air transport system and mobility, and the integration of different transport modes into one coherent system. In this third annual Mobility Report, we present the results gathered and extracted using Artificial Intelligence (AI) and automated data analysis techniques from data on 926 selected European mobility research initiatives. These results were augmented through expert-based analysis, thus introducing a human into the loop, and providing a set of insights and recommendations for future research initiatives.



1

PROJECT INTRODUCTION

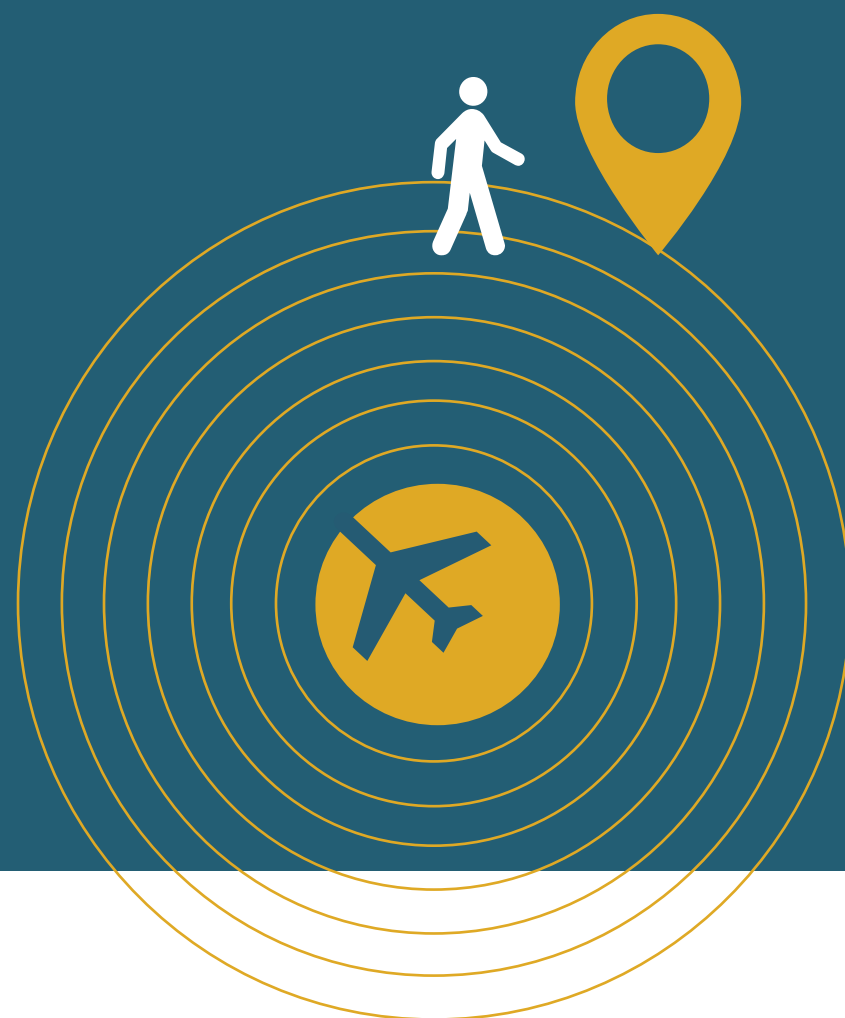


FIGURE 1:
CAMERA INCORPORATES
A EUROPEAN CONSORTIUM



What is CAMERA?

The EU-funded CAMERA (Coordination and Support Action for Mobility in Europe: Research and Assessment) project is coordinated by The Innaxis Foundation and Research Institute (Spain), in partnership with the University of Westminster (UK), Bauhaus Luftfahrt (Germany), EUROCONTROL (France-Belgium) and DeepBlue (Italy). It was launched in November 2017 for a duration of 48 months. The project investigates research initiatives into the European transport system from 2007, with a special focus on air travel, its integration with other transport modes, and passenger experience.

Air travel is too often observed from the point of view of its mobility providers (airports, air navigation service providers, airlines, etc.), and not often enough from the passenger perspective, although these are the end customers of air transport. However, the digital transformation of the past years has changed passengers' expectations of air travel, which they increasingly consider to be just one part of a wider journey. Observing the whole door-to-door process, a typical air travel itinerary includes various segments such as getting to an airport by road or rail, and passing through different airport processes on the way to the aircraft gate. In many itineraries, the time spent in the air is one of the shortest, maybe even the shortest, parts of the trip. Other main challenges for the mobility and aviation sectors include the current Covid-related crisis with its uncertain impact on mobility in the future, and environmental goals, which urgently need to be addressed.

To understand the complexity of the European air-travel system and address the mobility challenges it is facing, CAMERA's scope includes the whole door-to-door travel process and anything that has the potential to influence it. This holistic point of view is especially important in today's age of artificial intelligence, increased connectivity and personalised services. Moving towards a seamless, digital, environment-friendly and efficient door-to-door model, instead of focusing only on the gate-to-gate part of passenger itineraries, is becoming the norm for innovation in mobility.

Objectives of the CAMERA project

The CAMERA initiative aims to evaluate the impact of EU mobility-related projects in the context of current and future mobility challenges (see Figure 2). For this purpose, CAMERA focuses on developing an innovative and (semi-) automatic method that can:

Ingest data on European research projects funded by the FP7 and Horizon 2020 frameworks, and identify those that are most likely to be of interest to (air) transport and mobility.

Analyse the projects selected as being in scope and cluster them according to the challenges they tackled.

Assess the extent to which each mobility research project addresses the identified challenges.

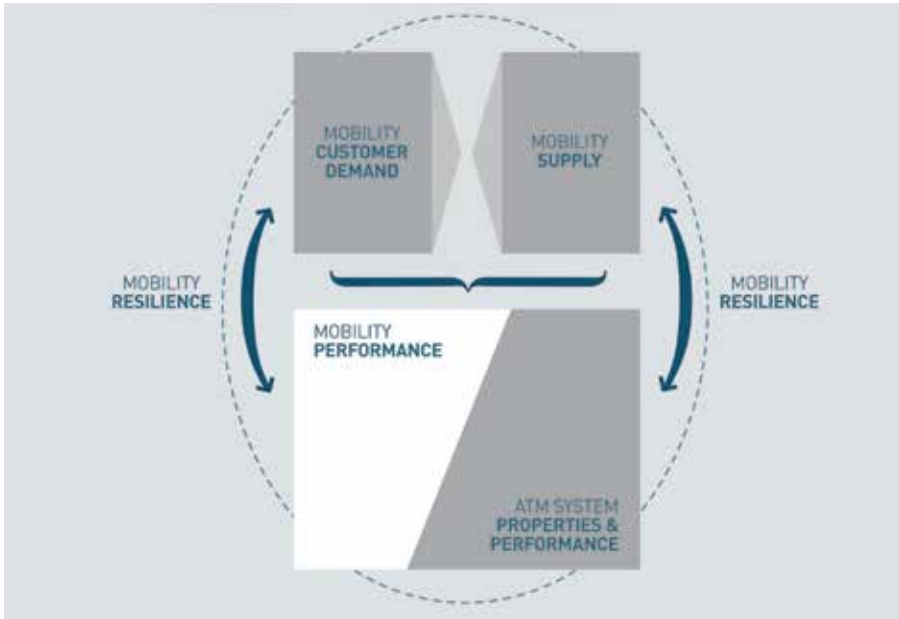
Provide a quantitative understanding of what challenges are being sufficiently investigated or, conversely, under-explored.

Eventually, CAMERA aims to answer two pressing questions: *Are EU-research and initiatives on the right trajectory towards reaching long-term goals in the (air) mobility sector? And How far is Europe from the mobility goals envisaged for the future?*

How CAMERA works

Each year CAMERA assesses projects from different research programmes to deliver a European view of the state of aviation and mobility-related research activities. For this, the team relies on two main corner stones to its project approach: 1) the systematic development of a Performance Framework to provide a means of measuring; and 2) state-of-the-art algorithms for an automated analysis of the research projects.

FIGURE 2:
CONCEPT MAP MOBILITY CHALLENGES



Performance Framework for assessing the projects and initiatives

CAMERA's Performance Framework was first developed as a conceptual approach that facilitates the measurement of progress towards European mobility goals. It incorporates the most pressing mobility challenges, represented as five mobility layers. These five layers are the Framework. Each layer presents a number of key performance areas (KPAs), derived from high-level goals stated in various strategic European transport agendas. They enable progress towards tangible goals for mobility research in Europe to be measured, and in turn allow the state, gaps and bottlenecks of latest research initiatives towards achieving those goals to be assessed. The development of this framework then progresses in consecutive steps as shown in Figure 3. Subsequent project activities take the Performance Framework with its developed mobility layers into account.



CORDIS PROJECT
REPOSITORY
<https://cordis.europa.eu>

To read extra content,
please scan these codes with
your QR CODE Reader.
If your smartphone is not
already equipped, please
consider downloading a
QR CODE reader from the
App Store or Google
Play Store.

The Natural Language Processing (NLP)
algorithms used by CAMERA

The Performance Framework is used as the basis for measuring the progress of projects towards European mobility goals. Techniques developed in CAMERA provide tools for performing an automated assessment of research projects. Such tools are based on natural language processing (in short NLP) algorithms, which determine the most common and relevant topics in a document by inspecting the probability distributions of words in its text. CAMERA applies these tools to the textual data on the EU-funded projects available in the CORDIS database, the European Commission's primary public repository for project dissemination.

This approach enables the team to analyse large volumes of unknown text without prior knowledge of the content of the documents and the subjects they addressed. In principle, with this technique it is possible to process all textual data available on CORDIS, without having to specifically restrict the scope to transport-related programmes. One direct benefit of this method is that it makes it possible to identify mobility-relevant projects from other application domains (e.g., ICT - Information, Communication and Technology), or in other programmes such as the SME Instrument (one of the main funding programmes for emerging small and medium-sized enterprises). Deploying these algorithms enhances our analytical capabilities for assessing and reviewing large datasets.

Looking both ways: top-down vs. bottom-up

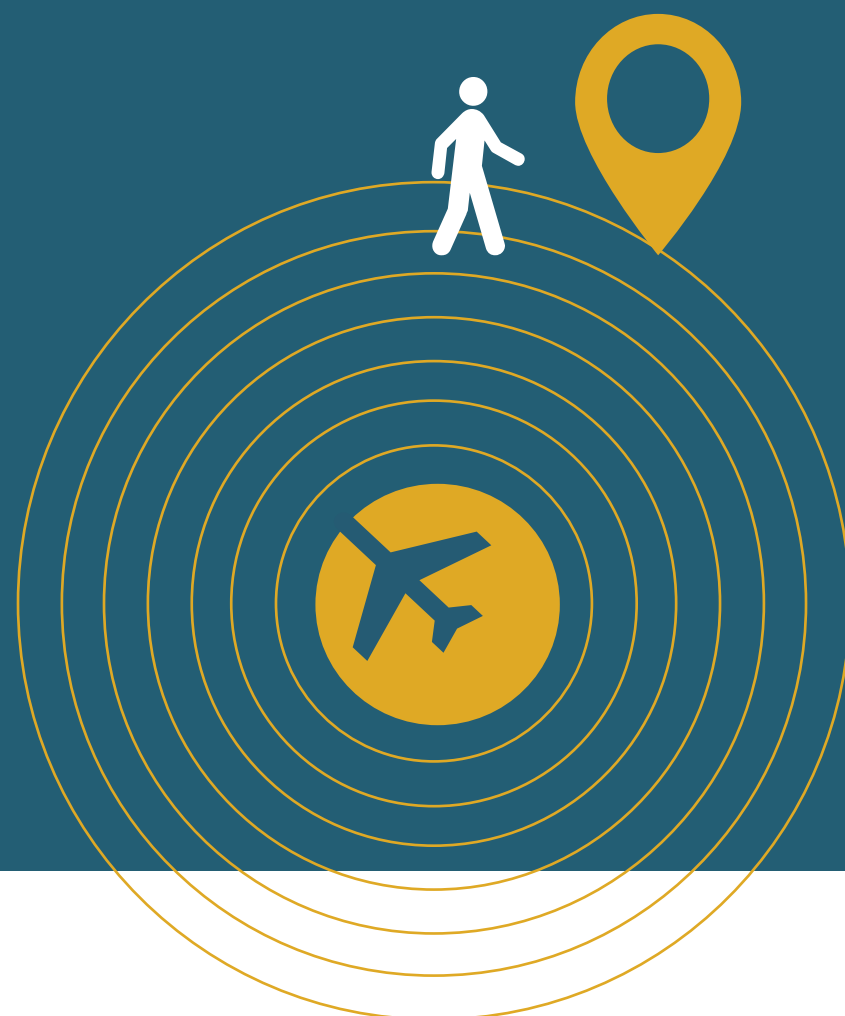
Throughout the project, CAMERA uses an innovative methodology. The automated quantitative analysis obtained through state-of-the-art algorithms is complemented by a qualitative analysis provided by human experts (introducing a human into the loop). Therefore, in working towards achieving its objectives, CAMERA combines a top-down (structured benchmark analysis of past and ongoing mobility-related activities) and bottom-up (separate consultations with stakeholders) approaches.

FIGURE 3:
CAMERA APPROACH FOR DEVELOPING THE PERFORMANCE FRAMEWORK



2

FUTURE MOBILITY CHALLENGES



H2020 PROJECTS
EU research projects
under Horizon 2020:
<https://bit.ly/2ckXLmz>



FP7 PROJECTS
EU research projects
under FP7:
<https://bit.ly/2Dgtbcv>

There are many diverse and pressing challenges that European countries need to address to enable the full realisation of Europe's vision for highly efficient, digital, multi-modal, sustainable, and climate-neutral mobility. Several transport research agendas include understanding the present and future challenges facing the European transport system and turning them into measurable objectives.

Aviation plays a major role in this research. In the CAMERA project, these challenges and their related objectives are combined and translated into the five CAMERA mobility layers outlined in the Figure 4. Although CAMERA puts air transport at the heart of the mobility system, it adopts a broader passenger viewpoint by considering the entire door-to-door journey. Air travel is only one leg of a passenger's journey that also includes the trips to and from the airports and finding their way within the terminals. Airport access and egress often form the longest part of a trip. Since CAMERA does not just look at one single leg of the passenger journey, it pursues a wider mobility scope by considering the interaction between different transport modes, and the performance of the overall system. This approach is reflected in the definition of the CAMERA mobility layer challenges. An extensive discussion of the layers and the development of the CAMERA Performance Framework is presented in the project's Deliverable 2.1. 'Establishment of Performance Framework' [1].

The CAMERA project follows a data-driven approach, using publicly available data from European research programmes, to determine how well the European research landscape is meeting these challenges. It investigates research initiatives from the past decade under the FP7 and H2020 funding programmes that focus on the European air transport system and its integration with other transport modes.

To read extra content, please scan these codes with your QR CODE Reader.
If your smartphone is not already equipped, please consider downloading a QR CODE reader from the App Store or Google Play Store.

FIGURE 4:
OVERVIEW CAMERA PERFORMANCE FRAMEWORK (KPAS AS DEFINED
BY ICAO IN THEIR MANUAL ON GLOBAL PERFORMANCE OF AIR NAVIGATION SYSTEM)

LAYER #1

Creating an individualised and seamless mobility system for everyone.

LAYER #2

Improving the overall performance of the mobility system.

LAYER #3

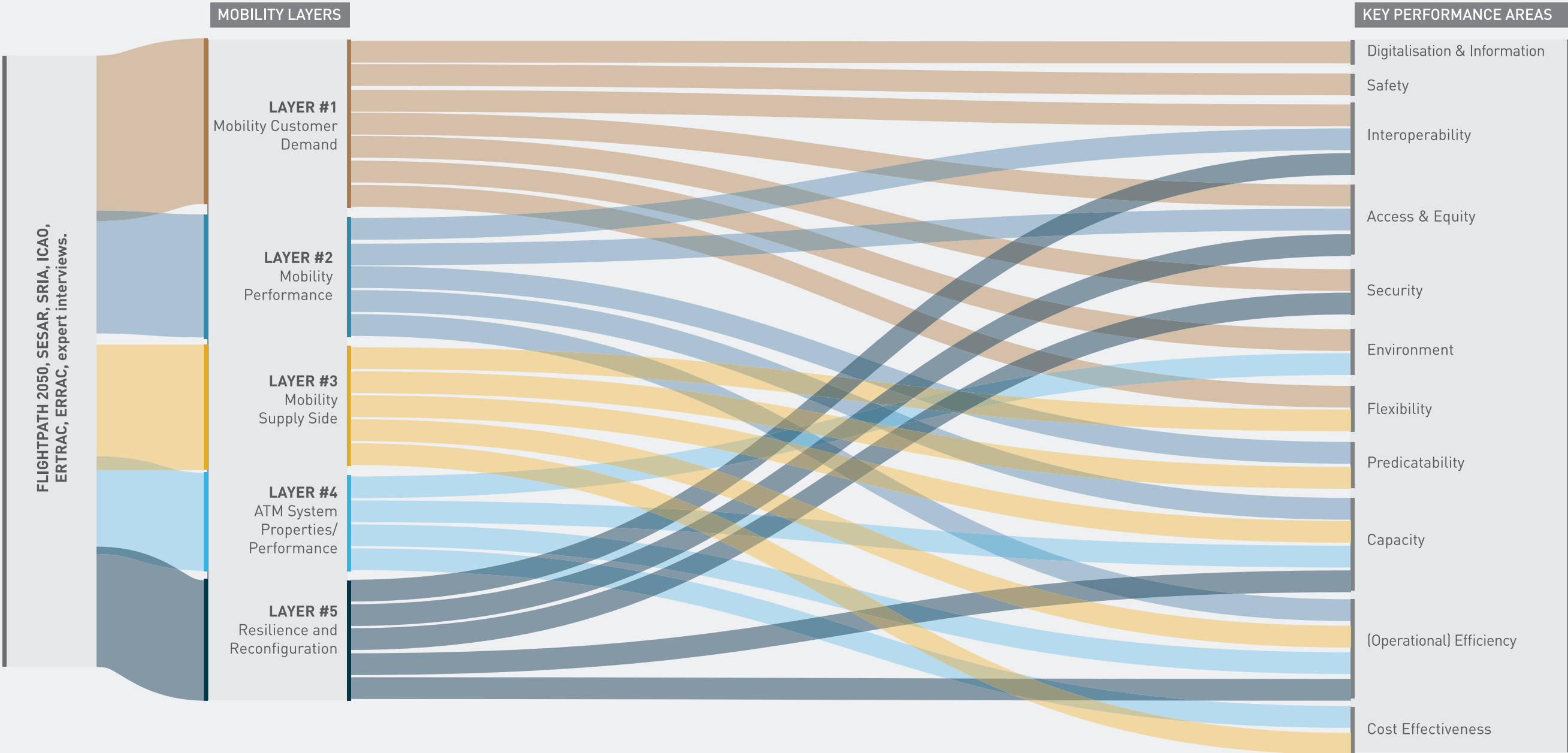
Improving the resilience and re-configuration of the mobility system.

LAYER #4

Providing safe and efficient air traffic management (ATM) services.

LAYER #5

Designing and implementing an integrated, intermodal transport system.



CAMERA FRAMEWORK
Deliverable outlining CAMERA definitions,
structure and methodology:
<https://bit.ly/2MKAxg9>

3

WHAT DOES CAMERA ANALYSE: MOBILITY RESEARCH INITIATIVES

EU-funded mobility research activities involve consortiums whose members come from all over Europe. The assessment in this section provides an in-depth descriptive analysis of the geographical distribution, the lead coordinator, and the historical evolution of the projects, together with information on the project size, etc.

All the results are generated using state-of-the-art data mining and predictive modelling techniques. The dataset to be analysed is obtained using the automated text-mining approach developed in the CAMERA project. In total, 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. The results show clear differences between the funding programmes and countries.

**As we will see below regarding Clean Sky 2 initiatives, Integrated Technology Demonstrators (ITDs) have co-leadership structures. For the sake of simplicity in reporting, in this document we will describe large, collective activities in Clean Sky 2 such as ITDs and Innovative Aircraft Demonstrator Platforms (IADPs), as 'projects'.*

Geographical distribution

A coordinating entity (coordinator) performs a project's coordination function. The main responsibilities of the coordinator are launching and leading the project, monitoring project-related activities, acting as the intermediary between the consortium and the European Commission, taking care of financial matters, and submitting deliverables and reports. Figure 5 shows the distribution of the countries coordinating the 926 projects analysed. The map reflects a broad geographical range of institutes leading mobility research projects with several countries established as leading hubs of mobility research coordination. With 139 projects, Germany coordinates the greatest number of research activities, followed by Spain with 120 projects, France with 107, and United Kingdom and Italy with 106 projects each. As all of these countries are relatively strong European economies with large populations, these results were somewhat expected.

FIGURE 5
NUMBER OF COORDINATED
PROJECTS PER COUNTRY
(BOTH COMPLETED AND
ONGOING PROJECTS)

TOTAL NUMBER
OF PROJECTS

926

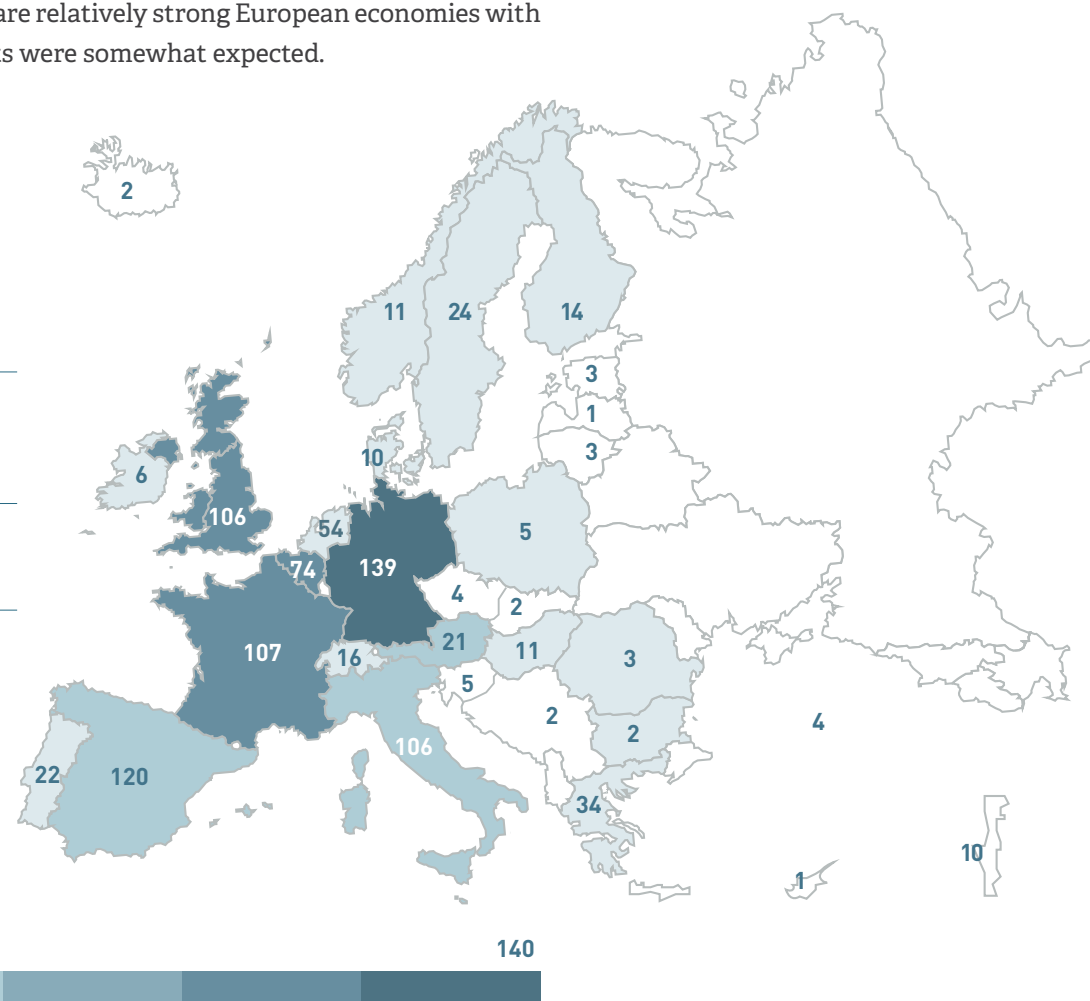
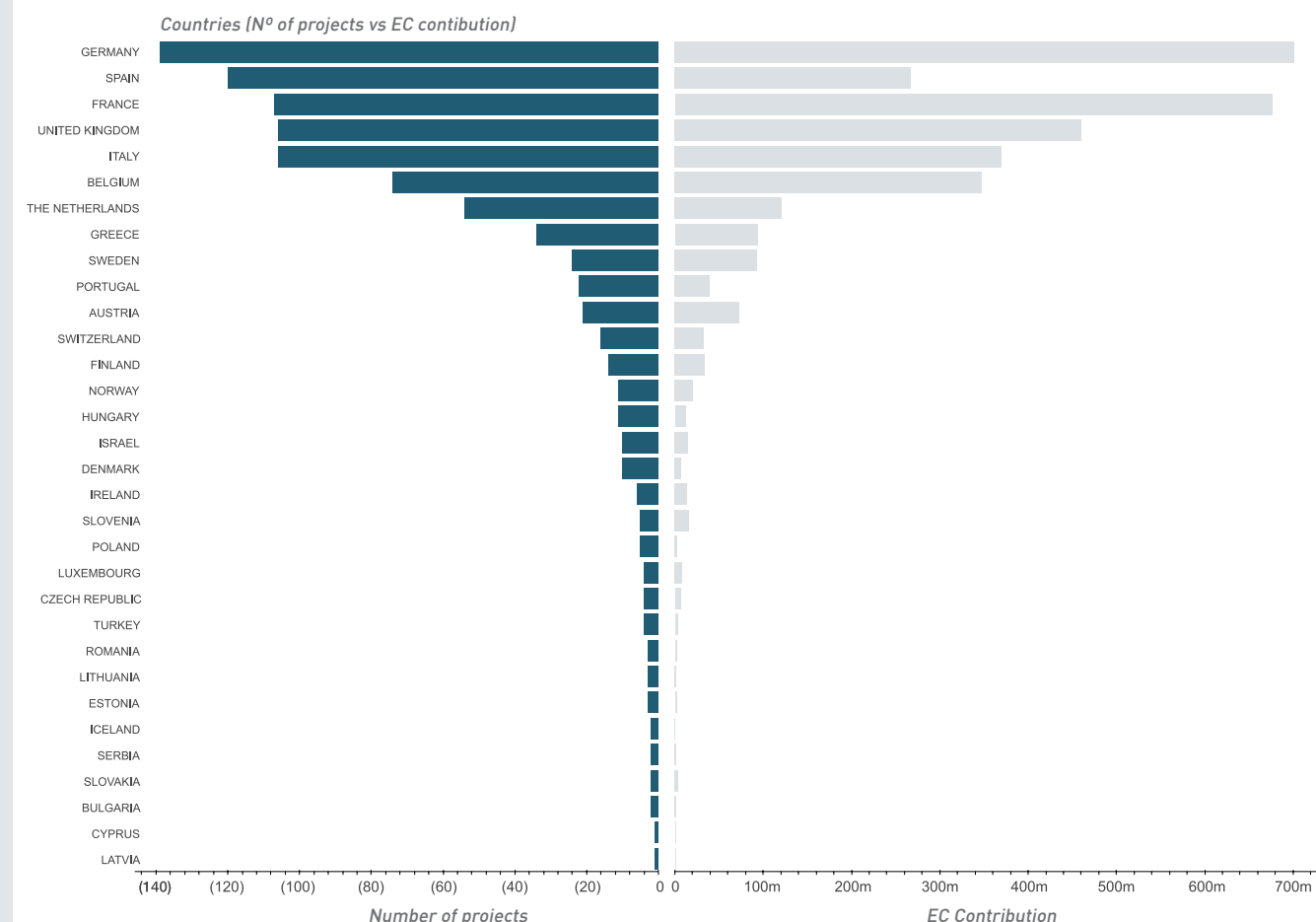


FIGURE 6:
COUNTRIES WITH TOTAL NUMBER OF PROJECT COORDINATIONS
AND EC CONTRIBUTION RECEIVED (IN €)



An overview of all the coordinating countries ordered by the total number of projects coordinated is given in Figure 6, together with the total financial contribution from the EC for all of the projects coordinated for each country. There seems to be a linear correlation between the total contribution received and the number of projects led. A few countries deviate from this trend, however. For instance, Spain coordinates the second highest

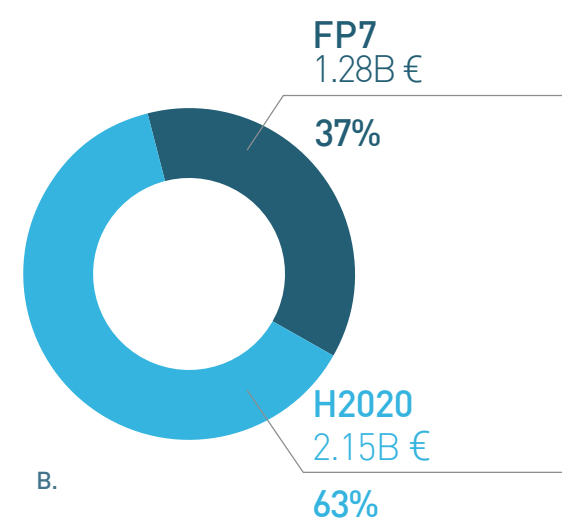
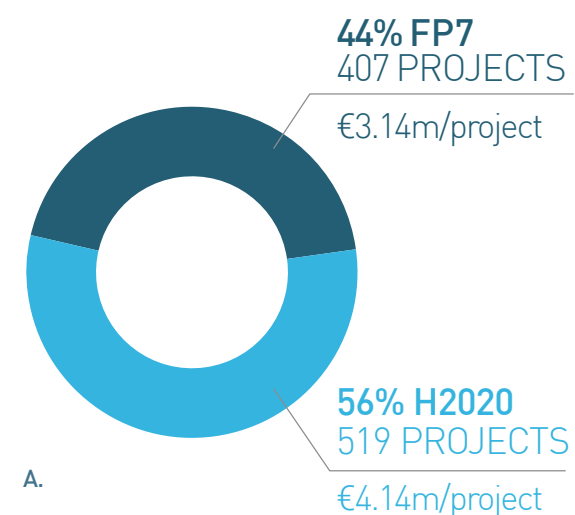
number of projects; the total contribution from the EC for these is fairly small. In addition, although France coordinates 32 projects fewer than Germany, the total EC contribution was almost the same in both cases. Such deviations could be explained by factors such as the number of consortium members, project duration (shorter projects could receive a much smaller amount of funding), and other specific project needs.

Project funding

The EC has spent around €3.4b on mobility-related research activities since 2007. On average, FP7-funded mobility projects received smaller EC contributions than H2020-funded projects. FP7 projects received an average funding of €3.14m, compared with an average funding of €4.14m for H2020 projects. H2020-funded projects received on average more than double the amount of funding from the EC than FP7-funded projects.

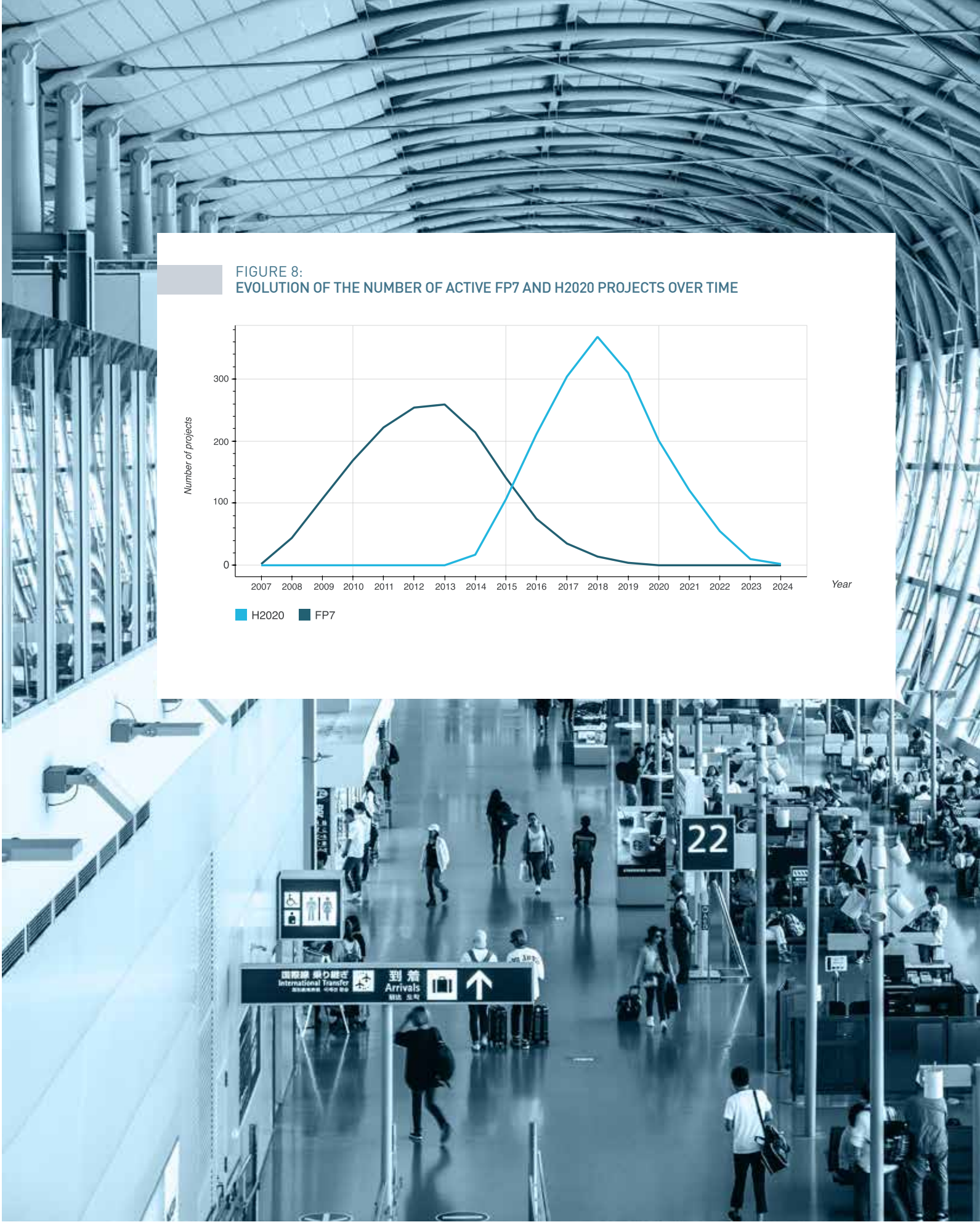
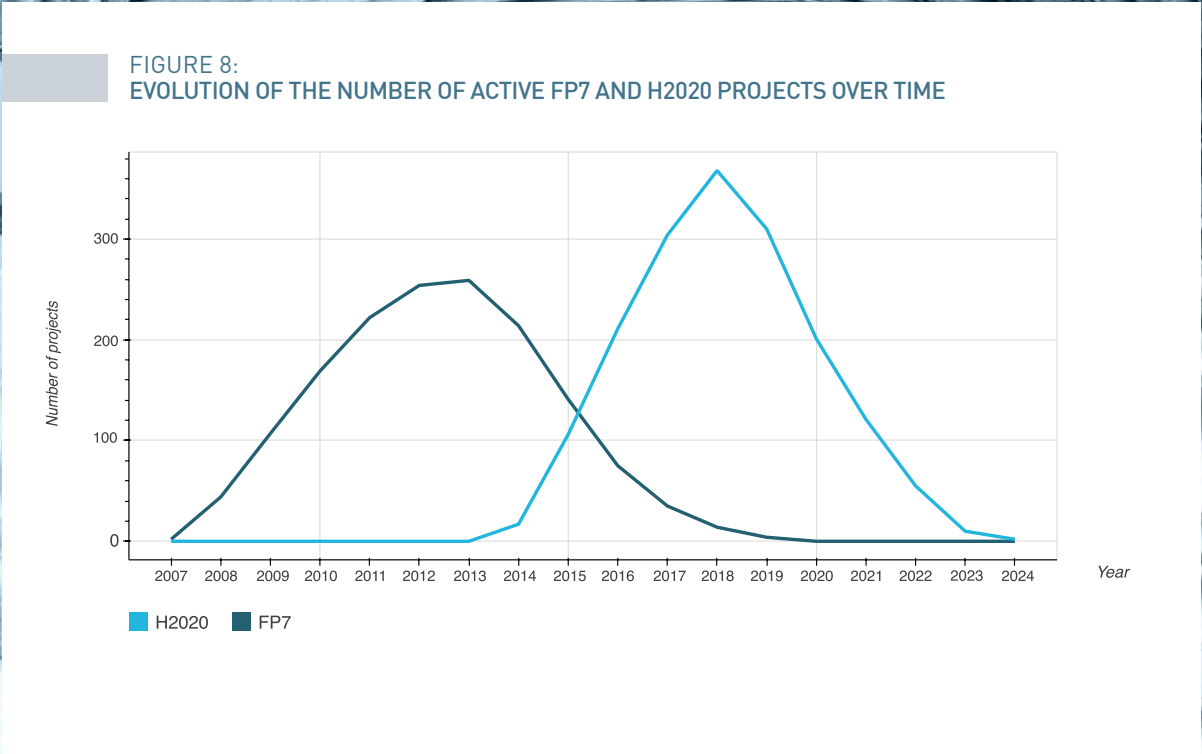
Other contributing factors could be the overall structure of FP7 projects, as more time could be given to preparing deliverables and reaching the overall project objectives. The greater average contribution per project-month that H2020 projects received in comparison with FP7 projects could be an indicator supporting this. FP7 projects also started much earlier in 2007, with the monetary value dropping over time due to inflation. It should be remembered that these figures are applicable to mobility-related projects only, not to the entire funding programme. In addition, our CAMERA analysis contains more H2020 projects than FP7 projects (519 vs. 407; cf. Figure 7).

FIGURE 7:
A. NUMBER OF H2020 AND FP7 MOBILITY-RELATED PROJECTS ANALYSED, B. TOTAL EC CONTRIBUTION PER FRAMEWORK FOR SELECTED PROJECTS (IN €)



Historical evolution

Projects funded under FP7 started in 2007 and those under H2020 started in 2014. Almost 80 FP7 projects were launched during the peak year (for start dates) in 2011. More than 120 H2020 projects represent the next peak of start dates five years later in 2016. Similarly, observing the curve that presents the number of active projects each year since 2007 (see Figure 8), it can be seen that the peak of research activity in mobility research in FP7 was reached in the years 2012 and 2013, with around 250 ongoing projects. On the other hand, the most active year for mobility research under H2020 was 2018, with around 350 projects ongoing at that time. A project trough can be observed in 2014, within the transition phase from FP7 to H2020.



Exploring financing, project size and project duration

Average project financing, project size and duration for both H2020 and FP7 programmes is very similar. As can be seen in Figure 7 both programmes have a fairly comparable average EC contribution per project, but they become nearly identical if we remove the large collective activities in Clean Sky 2 (H2020= €3.144m and FP7 = €3.138m), presented in Table 14, from the calculation. Most projects have a duration of 24, 36, or 48 months, the average for H2020 being 2.4 years and for FP7 2.9 years. H2020 projects have an average consortium size of nine members and FP7 projects an average of eleven members, where the consortium size is the number of participating entities plus the coordinating entity. As mentioned above, there does not seem to be a substantial difference between H2020 and FP7 but for a fuller understanding, a more in-depth analysis was performed on the different initiatives in the two programmes. Figures 9 and 10 present the top ten initiatives by total number of projects for H2020 and FP7 and their total EC contributions (excluding the large collective activities in Clean Sky 2). These initiatives make up 93.4% of the projects in H2020 and 97.1% in FP7. The first thing that stands out is that in both cases there is no clear, direct correlation between the total EC contribution and the number of projects per initiative. In H2020 the top ranking initiatives tend to have a high total EC contribution while in FP7 the bottom ranked initiatives are the ones that present higher total EC contributions.

FIGURE 9:
TOP 10 H2020 INITIATIVES WITH RESPECT TO THE TOTAL NUMBER OF PROJECTS
(*LARGE COLLECTIVE ACTIVITIES EXCLUDED)

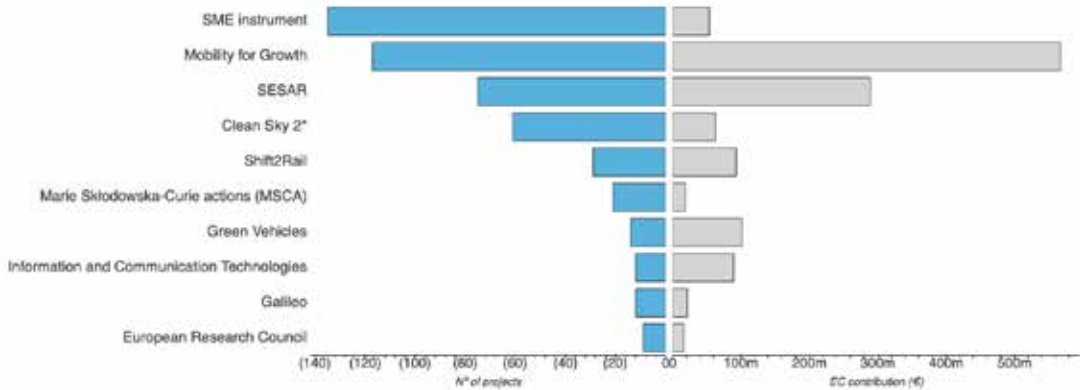
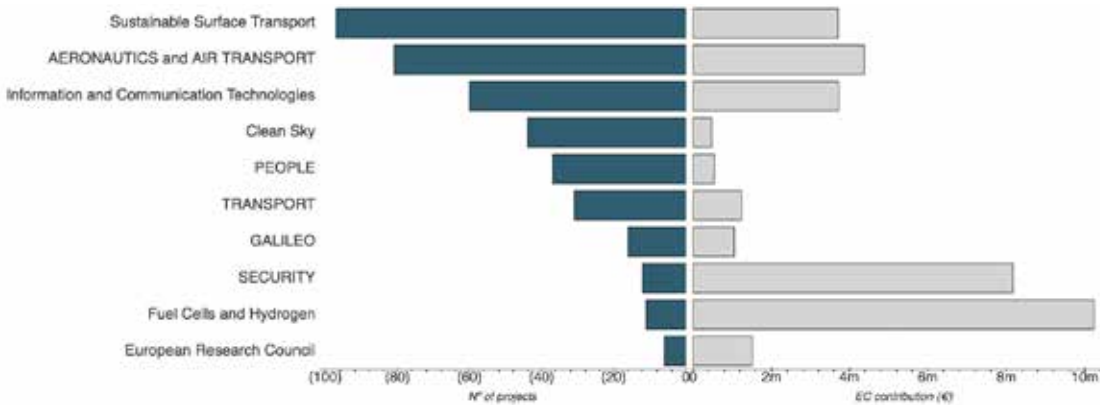


FIGURE 10:
TOP 10 FP7 INITIATIVES WITH RESPECT TO THE TOTAL NUMBER OF PROJECTS



Figures 11 and 12 give a better view of the relationship between the average consortium size, EC contribution and duration, for the different initiatives of the two programmes. For H2020 initiatives, Figure 11 shows that there is no clear correlation between the average duration of the projects and the average EC contribution and average size of the consortium. Most of the initiatives have an average project duration between 24-48 months. The figure shows, however, that there is some correlation between the consortium size and the average EC contribution per project; H2020 initiatives that have large consortium sizes tend to have a higher average EC contribution per project. The top five initiatives by average EC contribution are also the top five initiatives by average consortium size (more than ten members).

Figure 12 also shows a correlation between the average consortium size and the average EC contribution per project in FP7 initiatives. In terms of average project duration three distinct groups can be found. The first is initiatives with an average duration of between 24-36 months (there were no unusually short duration initiatives in FP7). These initiatives have small consortiums (fewer than ten members) and small EC contributions. Initiatives in the second group have an average duration between 36-48 months, tends to have big consortiums (more than ten members) and large EC contributions. The third group includes those initiatives with unusually high durations. Here we find an initiative with a small consortium and a small EC contribution, similar to the ones in H2020 but, on the contrary, there is also an initiative with a large consortium and a large EC contribution. For both H2020 and FP7, the consortium size tends to be correlated with the EC contribution. Initiatives with bigger consortiums have, on average, higher levels of EC contribution.

FIGURE 11:
AVERAGE PROJECT CONSORTIUM SIZE, EC CONTRIBUTION AND DURATION
(*LARGE COLLECTIVE ACTIVITIES EXCLUDED) OF THE TOP 10 H2020 INITIATIVES

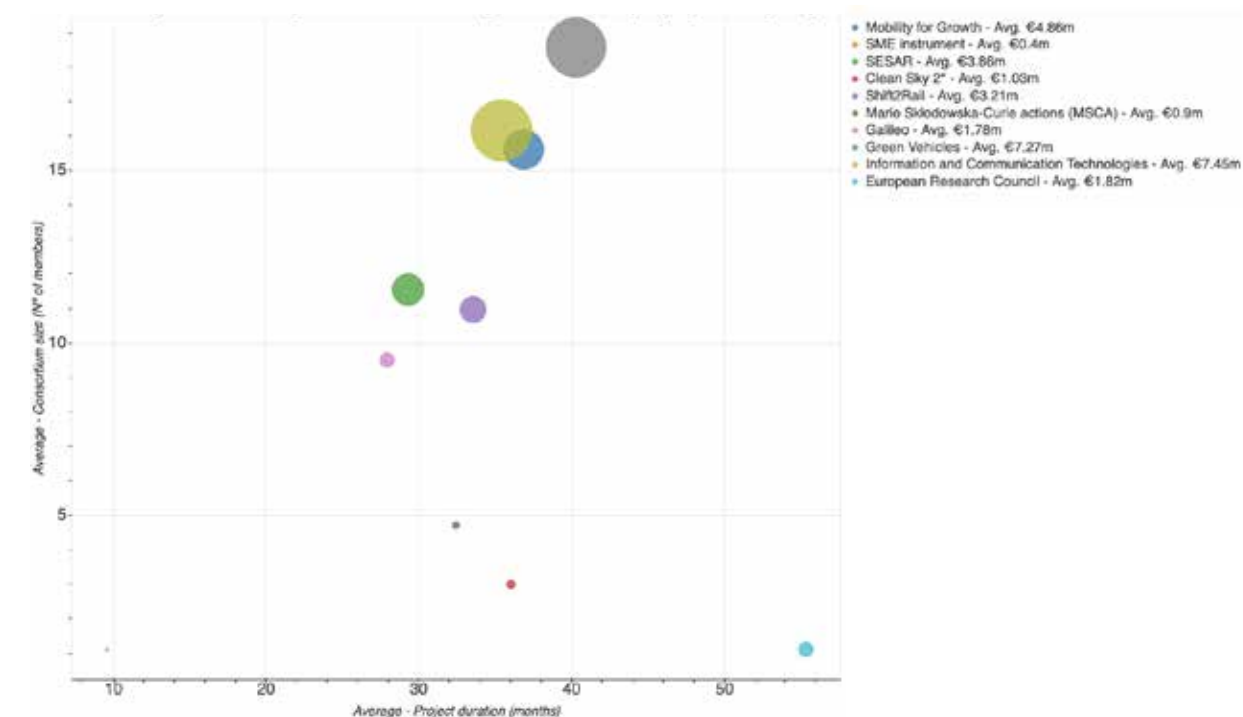
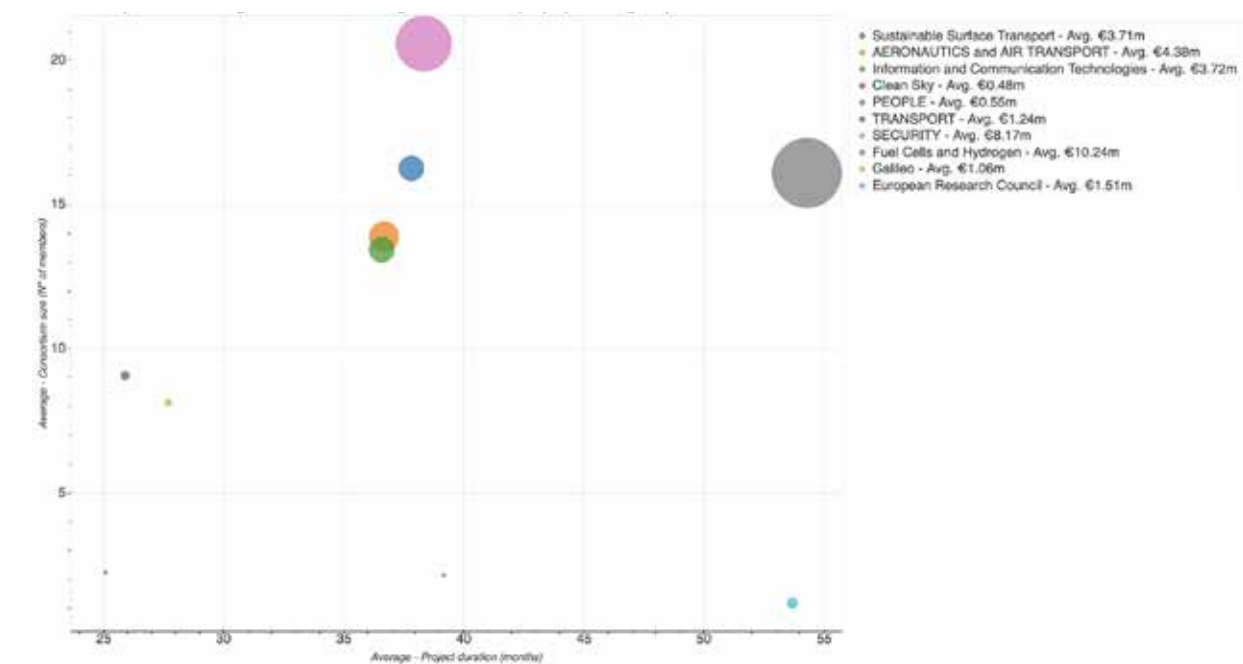


FIGURE 12:
AVERAGE PROJECT CONSORTIUM SIZE, EC CONTRIBUTION AND DURATION OF THE TOP 10 FP7 INITIATIVES



Larger funding activities

There are four H2020 'projects' (see Table 1) that are particularly large in terms of their funding (over €50m) and/or duration (6 years) and number of participants (29 or more). They all belong to the Clean Sky 2 programme. The structure of these requires some explanation. This programme has four elements: three ITDs (accommodating the main relevant technology streams for all air vehicle applications); three IADPs (involving demonstrations and simulations of several systems jointly at the full vehicle level); two Transverse Activities (integrating the knowledge of ITDs and IADPs for specific applications: Small Air Transport and Eco-Design); and the Technology Evaluator (assessing the environmental and social impact of the technologies developed in the IADPs and ITDs). Each demonstrator or platform identified in our analyses (classified simply as a 'project' above) is coordinated by a large corporate organisation, rather than a research institute. In Clean Sky 2, as in Clean Sky 1, ITDs have co-leadership structures, and two of these are shown in the table.

TABLE 1(NEXT PAGE)
LARGER CLEAN SKY 2 TECHNOLOGY DEMONSTRATORS
AND DEMONSTRATOR PLATFORMS

Clean Sky 2 programme activity	Technology Demonstrator/ Demonstrator Platform	Lead partner(s) (state(s))	Participants	Total budget (€m)	Summary details	Further information
Integrated Technology Demonstrators (ITDs)	System ('SYS')	Thales AVS France (France), Liebherr (Germany, France)	55	114.6	This ITD's includes most major aircraft systems: cockpit and avionics; environmental control systems; wing ice protection; electrical power generation, distribution and conversion; flight control systems and actuation. A joint focus is increasing electrification to enable the future more-electric or full-electric aircraft and creating environmentally friendly technologies, in particular for materials and processes.	www.cleansky.eu/systems
	Engine ('ENG')	Safran (France), Rolls-Royce (UK), MTU Aero Engines (Germany)	29	171.9	This ITD in Clean Sky 2 will build on the success of Clean Sky 1's Sustainable and Green Engines (SAGE), where the goals were to validate a 15% reduction in CO2 (compared to 2000 baseline), a 60% reduction in NOx and a 6dB noise reduction. This is roughly 75% of the ACARE objectives. The ITD will validate more radical engine architectures to a position where their market acceptability is not determined by technology readiness.	www.cleansky.eu/engines
Innovative Aircraft Demonstrator Platforms (IADPs)	Regional Aircraft ('REG')	Leonardo Aircraft (Italy)	34	52.8	This IADP's objective is to integrate technologies for regional aircraft with respect to Clean Sky's Green Regional Aircraft ITD. Retaining these outcomes, advanced technologies for regional aircraft are being further developed and will be integrated and validated at the aircraft level, so as to de-risk their integration with future regional aircraft products.	www.cleansky.eu/regional-aircraft
	Large Passenger Aircraft ('LPA')	Airbus (France)	41	192.2	This IADP is focussing on the large-scale demonstration of technologies integrated at the aircraft level, in three distinct 'platforms': [1] advanced engine and aircraft configurations; [2] innovative physical integration cabin – system – structure; [3] next generation aircraft systems, cockpit and avionics.	www.cleansky.eu/large-passenger-aircraft

4

ANALYSIS: EVIDENCE GATHERING



In this section, we present the evidence collected from the available data, using statistical analysis and data visualisation. As CAMERA is a data-driven project, the data are analysed in a semi-supervised algorithmic way, thus reducing a priori assumptions by humans and letting the model present its evidence almost by itself.

This way, we collect a range of statistical evidence and insight by transforming and aggregating the available data. The evidence is therefore obtained using state-of-the-art methods from data analytics, artificial intelligence and data visualisation.

The results of the quantitative part of the analysis performed in CAMERA are compared with those of the qualitative analysis. CAMERA performs 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.

Automated unsupervised topic modelling

The set of 926 mobility-relevant projects selected for the macro-analysis in CAMERA was modelled using unsupervised AI-based Natural Language Processing (NLP) methods with the goal of extracting the most common topics researched in the EU-funded mobility projects over the 13 years from 2007 to 2020. This means, among other things, that no mobility preconceptions were introduced into the analysis and that the findings are purely data-driven. The model developed has the ability to automatically detect similar topics across a corpus of textual documents and cluster the analysed documents (926 projects in our case) into the different topics detected.

Identification of most common research topics

Research topics

Table 15 gives an overview of the most common research topics identified using the unsupervised automated NLP model developed in CAMERA. A title was assigned to each topic by CAMERA's team of experts who reviewed and validated the automatic clustering, as well a world cloud with the 12 most relevant terms (keywords) extracted by the algorithm. Additionally, a short textual description provides the reader with a little more understanding of the particularities of each topic — such as the nature of the themes it covers.

The number of projects that have a given topic as their dominant topic, i.e. the number of projects best defined and described by this topic, was also determined for each topic. This information is presented in a more easily understandable manner as a pie chart in Figure 13.

TOPIC CLOUD 1 GREEN AIRCRAFT TECHNOLOGIES OF THE FUTURE

emission industry design new
technology impact engine market
aircraft cost fuel reduction

SUMMARY DESCRIPTION
This topic cloud is characterised by the study and development of novel aircraft technology enhancements, with a strong focus on alternative fuels and greener technological solutions.

NUMBER OF PROJECTS 103

TOPIC CLOUD 2 NOVEL CONCEPTS IN MOBILITY

information data city user
traffic service transport urban
travel provide public mobility

SUMMARY DESCRIPTION
This topic focuses on the development of new mobility platforms and strategies for improving urban mobility. It also includes mobility as a service and similar mobility-related concepts.

NUMBER OF PROJECTS 147

TOPIC CLOUD 4 INTELLIGENT MACHINES AND AUTOMATION IN TRANSPORT

human accident system road
traffic infrastructure safety task
risk change automation data

SUMMARY DESCRIPTION
This topic cloud identified topics with a strong focus on automation in transport systems and their safety as aspects of great importance.

NUMBER OF PROJECTS 42

TOPIC CLOUD 6 AIR TRAFFIC MANAGEMENT (ATM)

pilot operation flight concept
airport air aircraft aviation
traffic ATM cockpit trajectory

SUMMARY DESCRIPTION
This cloud serves as an umbrella topic for the improvements of any of the subsystems or components of the air traffic management system, e.g. runway capacity, trajectory optimisation, navigation and surveillance, and many others.

NUMBER OF PROJECTS 114

TOPIC CLOUD 8 MULTIMODAL TRANSPORT NETWORKS FOR BOTH PASSENGERS AND FREIGHT

rail stakeholder infrastructure impact
network scenario mode transport
measure railway european freight

SUMMARY DESCRIPTION
This topic cloud predominantly focuses on the study of transport systems as networks, covering various multimodal networks, logistics and freight transport, as well as rail transport.

NUMBER OF PROJECTS 93

TOPIC CLOUD 3 SECURITY SYSTEMS IN TRANSPORT AND MOBILITY

design architecture provide system
control solution security management
process technology service data

SUMMARY DESCRIPTION
The third topic cloud covers general security topics, from security of identification systems to physical security, with a strong data orientation.

NUMBER OF PROJECTS 152

TOPIC CLOUD 5 GREEN URBAN MOBILITY TECHNOLOGIES

energy bus system hydrogen
urban demonstration vehicle
electric public fuel cell city

SUMMARY DESCRIPTION
The focus of this topic is green transport solutions and novel technologies for ground transport and urban mobility.

NUMBER OF PROJECTS 70

TOPIC CLOUD 7 TRANSPORT MODELS HARNESSING THE POWER OF DATA

noise simulation design tool
develop model result test
analysis data method algorithm

SUMMARY DESCRIPTION
The main focus of this topic is developing projects or studying models of air transport systems. As such, this topic cloud has a strong data orientation and also includes studies of various emissions and noise models in transport.

NUMBER OF PROJECTS 81

TOPIC CLOUD 9 HIGH-LEVEL STRATEGIES FOR TRANSPORT INNOVATION

innovation european partner transport
workshop future support Europe
development programme work activity

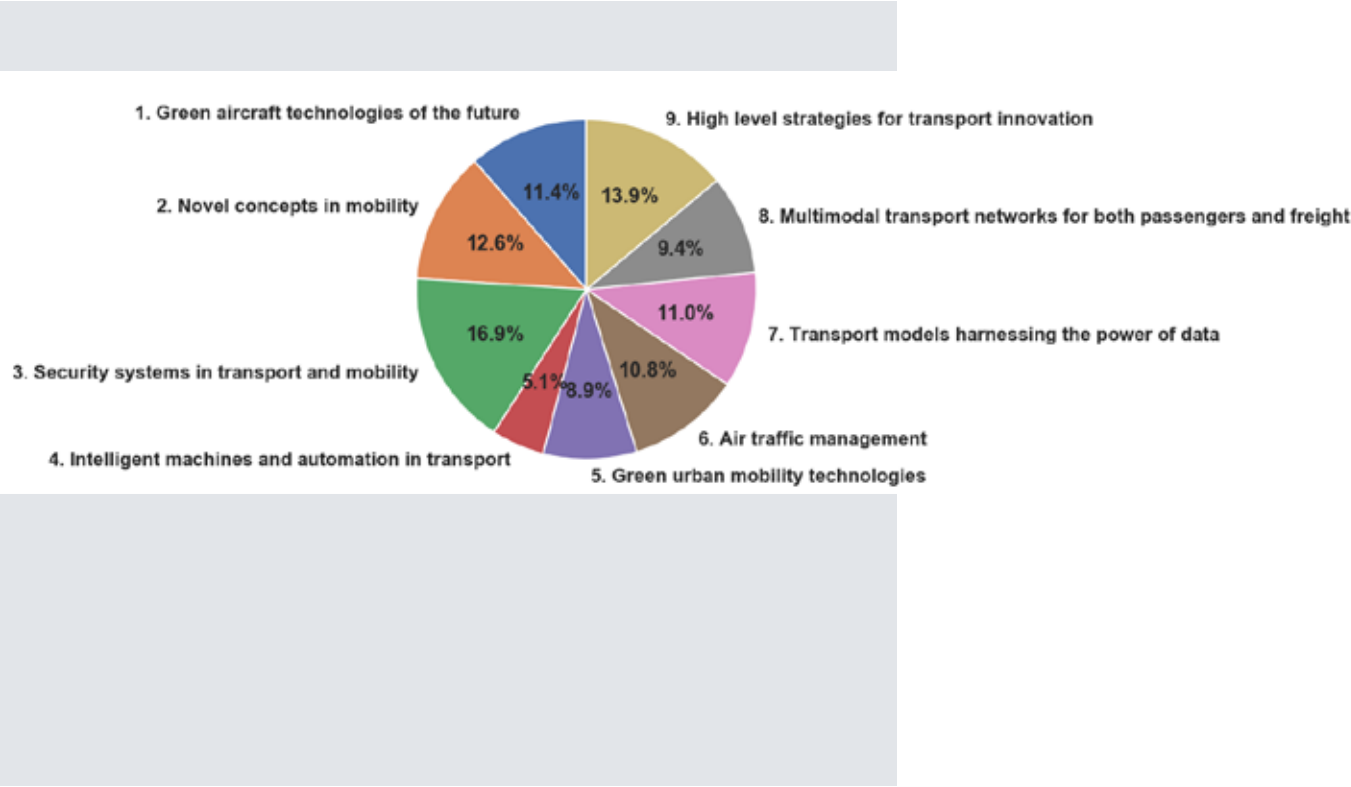
SUMMARY DESCRIPTION
This deals with high-level, strategic agendas addressing overall goals and challenges for future transport systems.

NUMBER OF PROJECTS 124

Topic representation in the data set

Figure 13 gives a representation of each topic in the set of all 926 projects analysed. The percentages in the pie chart can be interpreted as the likelihood that any given mobility project addresses (at least in some part) that research topic, thus providing an insight into how well each topic is covered in the set of research initiatives analysed. It is worth noting that the majority of topic clouds are fairly uniformly represented, although it can be seen that the topic with the highest coverage is number 3, Security systems in transport and mobility. In other words, the topic of security in transport is most likely to be studied in a randomly selected project. However, if we combine topics 1 and 5, which generally address the theme of green mobility, their share surpasses that of the security topic cloud. The least addressed topic cloud is Intelligent machines and automation in transport, which is not surprising since this a very novel technology and research area.

FIGURE 13:
REPRESENTATION OF TOPIC COVERAGE
IN THE DATA SET OF ANALYSED PROJECTS

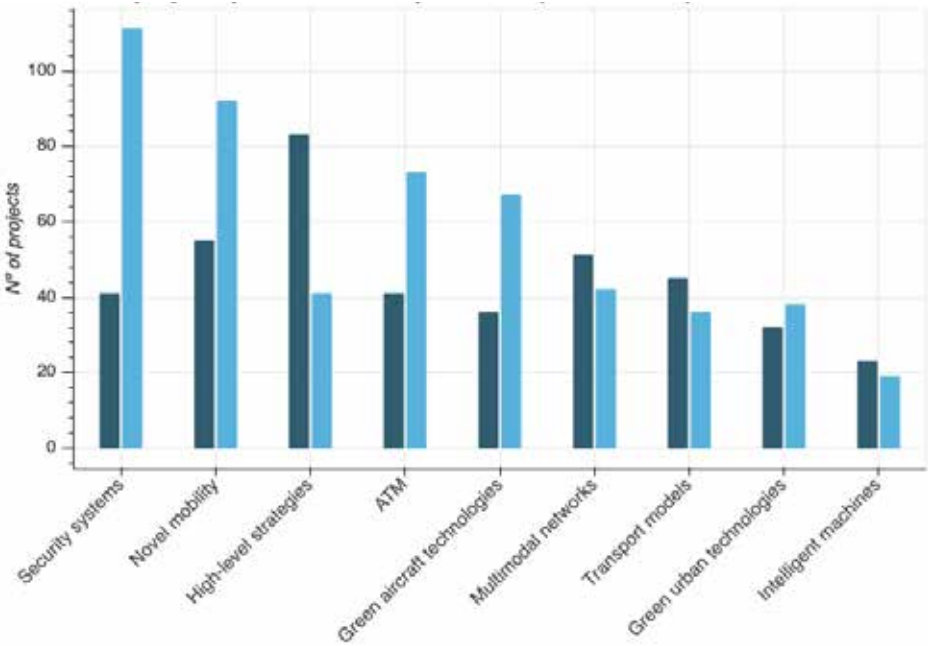


Distribution of projects over topics

Figure 14 show the nine identified research topics ordered by the number of projects to which that topic is assigned as the dominant one. While many research initiatives are multidisciplinary and sit on the intersection of two or more of the research topics identified in CAMERA, the automatic analysis approach has enabled the dominant topic in each project to be quantitatively identified as the focal point of the project. In some projects there is a very clear dominant topic, while in others the dominance level is not so prominent. The reader should therefore bear in mind that many projects are multidisciplinary with low levels of dominance and the dominant topic assigned to them might not be as significant as might be expected.

Intuitively, the bar chart on Figures 14 shows how well represented each topic is among the mobility-relevant projects analysed (taking into account only the dominant topic of each project) grouped by funding programme (H2020 vs. FP7). An interesting observation is that topic 9, dealing with high-level strategies, is the dominant topic of twice the number of FP7 projects than it is of H2020 projects. This could be explained by the fact that, since FP7 started before H2020, it carried most of the weight in defining overall goals, challenges, and milestones for transport research in the coming decade and beyond. Topics 3 (Security systems), 2 (Novel mobility), 6 (ATM), and 1 (Green aircraft technology) also contain significantly more H2020 projects than FP7 projects. This could be an indicator of a general shift in focus of more recent projects towards these research areas; a potential trend we take a closer look at in the section on trend analysis (below).

FIGURE 14:
NUMBER OF PROJECTS A TOPIC
CLOUD COVERS AS THEIR
DOMINANT TOPIC, GROUPED
BY FRAMEWORK PROGRAMME
(FP7 VS. H2020)

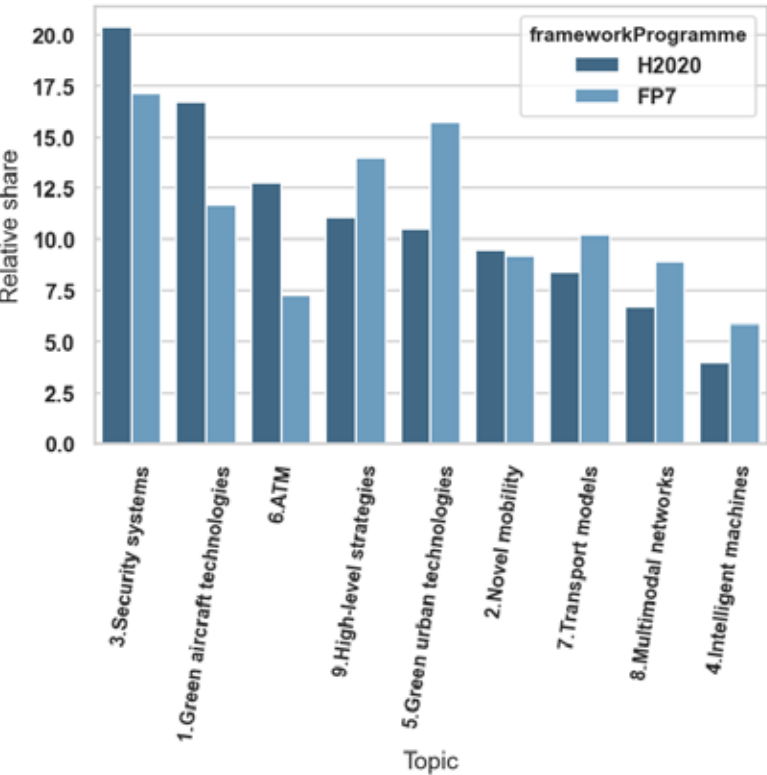


Financial analysis: topics

This section presents an analysis of the financial contribution that projects received in relation to their identified research topics and yearly evolution.

Figure 15 shows the relative financial share that each of the identified research topics received from the EC across all projects and how financial objectives shifted in the transition from the FP7 to the H2020 framework. Topic 3 received the most financing in both framework programmes. While the topic with the second greatest investment in H2020 is Green aircraft technologies, this received much less funding in FP7. However, the topic with the second highest investment in the FP7 programme was Green urban technologies. This indicates that sustainability and emission reduction have always been important aspects of mobility and have always received sizeable investment, but that the focus has perhaps shifted more towards air transport in recent years; this aligns with current social trends and burning issues in mobility and transport.

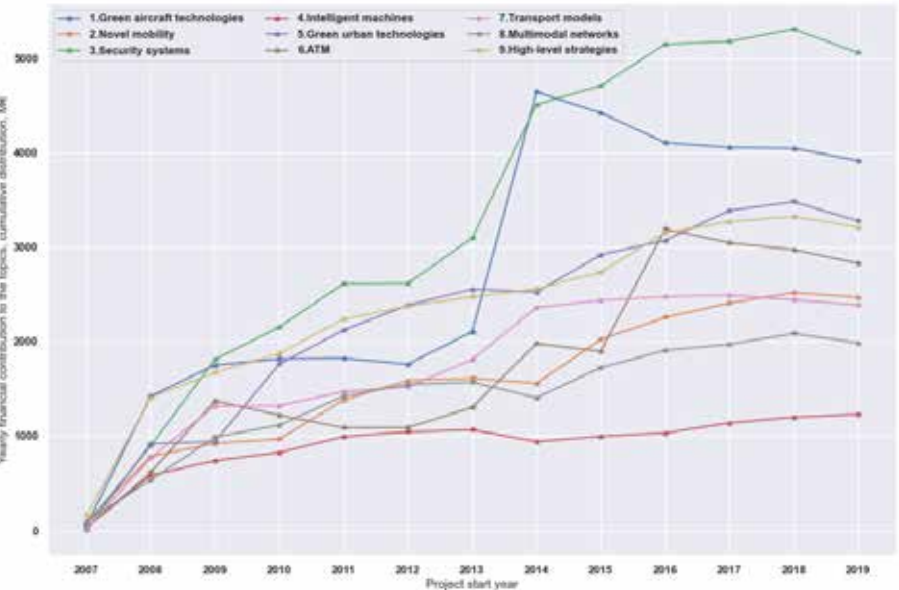
FIGURE 15:
RELATIVE FINANCIAL CONTRIBUTION TO EACH TOPIC:
H2020 VS. FP7 COMPARISON



In general, the evolution of financial investments plotted by the start-year of a project in Figure 16 shows that the research topics most invested in across H2020 and FP7 mobility projects are Security systems (3), Emissions (1, 5;) with an upward trend towards cleaner Air transport technologies), and Air traffic management (6).

Peak financing for the Green aircraft technologies of the future (1) topic occurred in 2014, after which it decreased slowly. The Security systems (3) topic has had consistent year-on-year growth, as has did Green urban technologies (5). Transport models (7) had very rapid growth until 2014, after which it stagnated. Notably, all research topics but the fourth, Intelligent machines, experienced a drop in investment in 2019, as shown in Figure 16: this is most likely due to a data artifact (there are not many projects with 2019 as their start year).

FIGURE 16:
FINANCIAL YEARLY TRENDS PER TOPIC CLOUDS, RELATIVE GROWTH



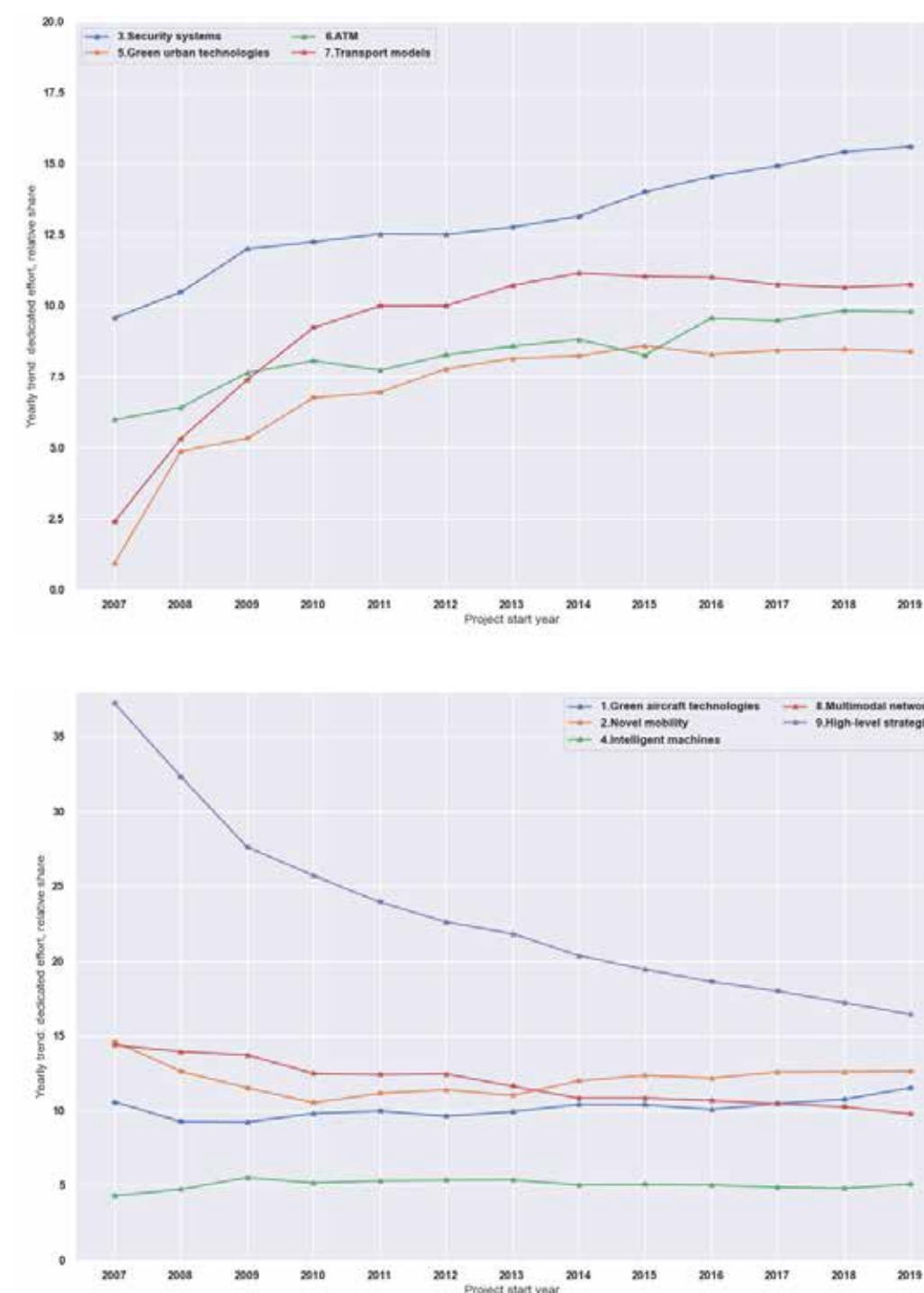
Trend analysis: how the focus moved over the duration of the framework programmes

Figure 17 shows how the research topic focus of the projects has moved over time. Project start-year is the only reference variable taken into account in this analysis, to the exclusion of other related variables, such as project duration. While such variables would slightly change the graphs given in Figures 17a and 17b, the start-year of a project is considered sufficient to provide a clear picture of how research trends evolved.

The High-level strategies (9) topic had its peak at the beginning of the FP7 programme in 2007 and declined in annual share thereafter. On the other hand, some research topics have gained more visibility and research focus since the inception of FP7, such as Security systems (3). Topics 8 and 9 generally trended downwards, more so topic 9 (for reasons mentioned above, governed by the particular nature of this topic cloud). Topics 1, 2 and 4 (see Figure 17b) have maintained a stable focus. Topics 1 and 2 are research areas that have been quite well established over the years, whereas topic 4 has occurred significantly less due to its futuristic nature; however, a rise in its popularity is likely as these technologies become better understood, increasingly mature, and more widespread.

When it comes to topic clouds where an increasing focus (upward trend, topics 3, 5, 6 and 7; see Figure 17a) is more prevalent, significant differences can be seen in the rate of growth in popularity among them. Topic 3, with its focus on security, maintains a strong presence over the years - its popularity continuously rising. This indicates that the importance of this topic is well established and is expected to grow further. A similar trend can be observed with topic 6, Air traffic management, that was consistently researched throughout both FP7 and H2020 programmes. However, the Green urban technologies (5) and Transport models (7) topics have experienced accelerated growth since 2007. This can easily be attributed to a societal shift, as environmental aspects of transport and mobility grew in importance in the 2010s and the data revolution increased the need for data-driven applications and studies.

FIGURE 17:
EVOLUTION OF THE DOMINANT TOPIC CLOUDS FROM 2007 UNTIL
2019 (PROJECTS SORTED BY THEIR START DATE). A) PREDOMINANTLY
UPWARD TREND; B) PREDOMINANTLY DOWNWARD OR STABLE TREND



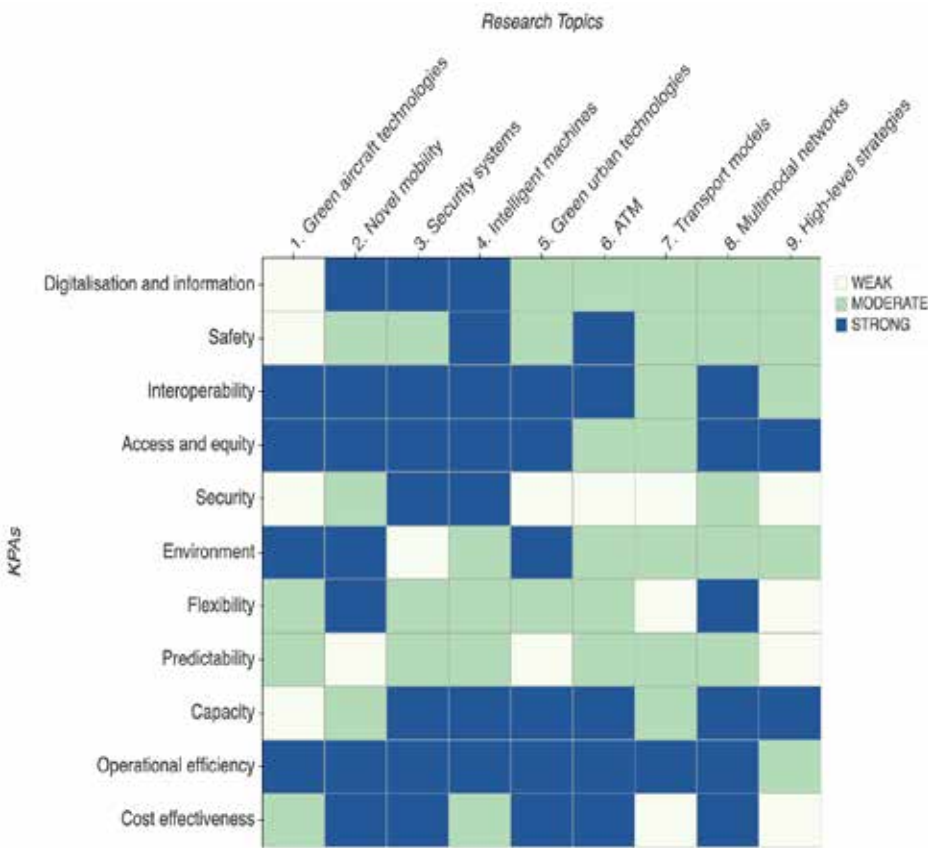
Key Performance Areas (KPAs): towards introducing expert assessment in the loop

The automated approach to analysis in CAMERA is supported by various expert assessments. In this section, we analyse the status of key performance areas (KPAs) and their respective key performance indicators (KPIs) as defined in the CAMERA performance framework. The automated approach allowed us to categorise, aggregate and thus present information on the research initiatives in a way that is easier, timesaving and more comprehensive for humans (e.g. relying on different aggregate statistics and metrics). This further allows us to support the automatic approach with expert-based assessments in CAMERA.

To analyse the status of KPAs defined in the CAMERA performance framework across different mobility research initiatives and the nine identified research topics, a keyword-based approach was adopted: the team of experts in CAMERA defined an exhaustive list of keywords for each KPA (see Annex 2) relying on their expert knowledge and the content of the performance framework. These keywords were used to algorithmically assess the mobility projects against KPAs and thus generate a series of metrics. The metrics will further enable a reduction in the workload of human experts when assessing the KPAs against mobility projects and their research topics, effectively acting as guidance for the qualitative analysis. In this section, we present the preliminary results of the analysis that will be put toward as a complementary tool for expert based assessment, and present a set of accompanying recommendations.

he set of observations and recommendations given in this section will be refined in the scope of the fourth and final CAMERA Mobility report, that will make use of the greater availability of results of H2020 research projects, and further supported by the micro-analysis in which we will focus on a narrow set of carefully selected mobility projects in greater detail.

FIGURE 18:
RESEARCH TOPICS VS KPIS COVERAGE HEAT MAP



Are we doing the right research?

In this analysis, CAMERA's performance framework-based, automated analysis approach, and expert assessment (human in the loop) were brought together. The heat map in Figure 18 shows at a glance the match between the defined research topics and KPAs as described by their respective keywords defined by experts. KPAs in turn represent the mobility challenges from the performance framework. We assume that a low match in this analysis is indicative of a potential low research coverage. Several topics match with the KPAs very well, i.e. they have a strong match (represented by the blue boxes). In addition to strong matches, two other categories are defined: moderately and weakly matched (mint green and eggshell-coloured boxes). These are the categories in which the respective KPAs are moderately or not well covered by projects that deal with the corresponding research topic. In short, these results deliver a point of view of the state of aviation and mobility-related research activities in Europe in the light of present and future mobility challenges.

The Operational Efficiency, Interoperability, and Access and Equity KPAs have a strong correspondence to a high number of research topics. Hence, one can conclude that these three mobility challenges (KPAs) are well studied and researched overall, and are on the right trajectory towards reaching their goals. Conversely, the Security, Predictability, and Flexibility KPAs have the weakest coverage and thus, in general terms, the challenges defined in these areas should be more intensively covered in a wider array of mobility projects.

The Novel mobility (2) topic focuses on the development of new mobility platforms and strategies for improving urban mobility. It also includes mobility as a service and similar mobility-related concepts. Projects in this topic conduct research on many pressing mobility challenges. The topic matches well with the Digitalisation (Digital transformation) & Information, Interoperability, Access & Equity, Environment, Flexibility, Operational Efficiency, and Cost Effectiveness KPAs. This could be a sign of the broad research scope of novel mobility concepts.

The Intelligent machines (4) topic incorporates research initiatives with a strong focus on automation in transport systems and their safety as aspects of great importance. It is not surprising that - among others - the objectives pertaining to the areas of Digitalisation (Digital transformation) & Information and Safety are well covered in this research topic. Other KPAs, such as Predictability and Cost effectiveness, are covered only moderately.

The High-level strategies (9) topic deals with strategic agendas that address overall goals and challenges for future transport systems. A high coverage of all of the KPAs would be expected, therefore. However, only the Capacity and Access and Equity KPAs are well matched, leaving the question of whether strategies and agendas really should work on expanding the mobility challenges they address and focus on their research scope. Going back to the

research topic trend analysis presented in previous sections, an educated assumption would suggest that this might be due to the evolution and change in research trends over the past decade. The 2010s was a very specific decade for extreme advances in technology (especially artificial intelligence) and an unprecedented increase in mobility and travel demand. From one hand, due to this increased demand, a large number of research initiatives focused on topics such as capacity, intermodality (related to the 4HD2D goal defined in Flightpath2050) and efficiency, since these were the burning issues in such a travel environment. On the other hand, a number of research topics emerged during the 2010s and started shaping the research focus in Europe, following other social, economical and technological trends: automation, focus on data-based decision making, intelligent machines, environment, and digital transformation. The effects of these trends can be expected to become more visible in the years to come, with the Covid-19 pandemic naturally drastically changing the most recent trends up to 2019.

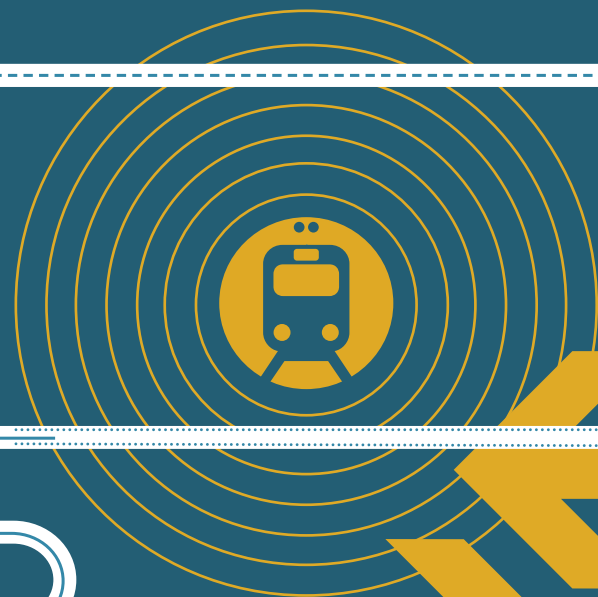
Another interesting fact is that the Security systems (3) topic incorporates the most projects (152) and is the most highly financed in both framework programmes. The Security KPA is on the other hand not well-matched throughout all projects, hence all security-related research questions seem to be covered in the Security systems (3) topic. The Green aircraft technologies (1) and Green urban technologies (5) topics have a strong match with the Environment KPA, which is to be expected. Overall, the results are feasible, and this shows a solid advantage of merging the automated approach and the human assessment of state of mobility research in Europe.

Some of the most pressing and highly debated mobility challenges in the current climate, more so shaped by the Covid-19 pandemic, Environment and Digitalisation & Information, fall somewhere in the middle of the heat map on Figure 18 when it comes to their coverage. These areas and their mobility challenges are essential to creating a sustainable future transport system and the recovery of mobility in the years to come, and more research in these areas is thus strongly encouraged. A more thorough analysis of this aspect will be performed in the coming year of the CAMERA project, taking the shift in mobility that the world is currently experiencing into account as much as possible.

Finally, one might question whether all project topics need to research all KPAs. For instance, should the topic on Green aircraft technologies (1) incorporate Digitalisation (Digital transformation) & Information goals? This assessment requires further human-based micro-analysis and will be highlighted in the final CAMERA mobility report.

5

SUMMARY AND CONCLUSIONS



This mobility report presents a framework for analysing the current state of mobility research in Europe, updated since the last mobility report, and its path towards achieving the goals outlined in Flightpath 2050 and other high-level strategies. It comprises of several categorisation methods developed with the purpose of automatically extracting and systematising mobility-relevant research projects from the body of projects funded under FP7 and H2020.

It relies on novel artificial intelligence-based methods to deliver a series of aggregated statistics and data visualisations that can, in addition to providing standalone insights, serve as a tool for further human-based assessment.

The mobility goals that CAMERA sees as indispensable for creating a sustainable, seamless, and efficient transport system in Europe have been systematically organised into five mobility layers. In addition, the layers provide a further systematisation of mobility goals by categorising them into eleven key performance areas (KPAs) defined by ICAO, each with a number of measurable targets (key performance indicators, KPIs) that should be achieved. They are presented in detail in the performance framework published by CAMERA [1].

Moreover, CAMERA adopts a natural language processing-based method to elegantly and semi-automatically identify most common research topics in the studied corpus of mobility research projects, yielding that way a novel categorisation and set of metrics to contrast with the one provided in the CAMERA performance framework. Contrasting various categorisations enables us to perform a more sophisticated analysis, supported by a wider range of metrics and a balance between an algorithmic modelling approach and an expert-based assessment.

Mobility research projects analysed in CAMERA: main characteristics.



926
MOBILITY RELATED PROJECTS



32
COORDINATING COUNTRIES



555
COORDINATING ENTITIES



3,43B
EC CONTRIBUTION



9
IDENTIFIED TOPIC CLOUDS

In total, 926 mobility-related research projects were extracted from CORDIS. An initial analysis of the geographical distribution of all projects in scope produced fairly expected results, with the majority of research efforts concentrated in the largest European economies (Germany, Spain, the United Kingdom, France, and Italy). Entities from these countries coordinated 51% of all of the identified projects and managed 72% of the total EC contribution.

The mobility projects funded by the FP7 framework programme lasted, on average, several months longer than H2020 funded projects. On the other hand, an H2020-funded project received on average €1m greater financial contribution than an FP7-funded project. This is probably linked to the creation of different public-private partnerships (in form of Joint Technology Initiatives or Joint Undertakings) driving the research in several strategic areas through (very) large 'projects' * with strong industrial leadership. However, looking at the full set of projects analysed, no strong correlation could be found between a project's duration and the financial contribution it received from the EC.

Figure 19 below shows the nine most common research topic identified over the set of 926 mobility-relevant projects. While they differ regarding themes covered, there may be some level of contextual similarity between the definitions of these research topics. For instance, there is a proximity between clusters of research projects predominantly attributed to topics 1, 6 and 7 as they are all related to aviation research.

The research topic with the overall greatest financial contribution received is Security systems in transport and mobility. This indicates that, throughout the duration of FP7 and H2020, safety and security have been one of the

most focused-on topics in mobility and transport, with steadily increasing investment being made in this area. In contrast, the Intelligent machines and automation in transport topic is still rather a niche area of research, though one that has seen accelerated growth in recent years. Since it is a research area that is just emerging and becoming more mainstream, there are very few research institutes and companies in Europe dedicated to it. It is thus characterised by the lowest overall financial contribution, though it has very large consortium sizes and durations. Analysis of its financial trends showed a financial breakthrough a few years ago; since then, contributions to this area have grown slowly. This should change as these technological trends start to become more widespread in the community of mobility and transport researchers.

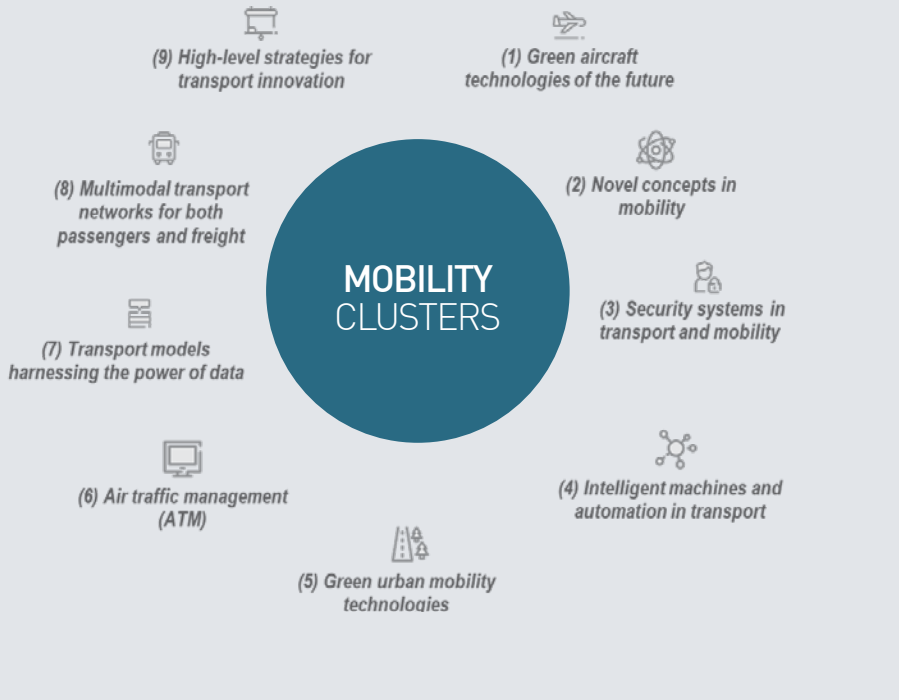
From analysis of the most common topics, it can be seen that FP7 and H2020-funded projects differ slightly in the topics they focus on. For example, FP7 projects significantly focus more on high-level strategies for transport innovation, a topic whose importance decreased quite significantly in the transition to the H2020 programme in 2014. The most likely reason for this is that a number of research initiatives in FP7 identified further research needs that were developed to a higher level in H2020.

A large amount of research effort was dedicated to the field of environmental impact of transport from the beginning of the FP7 programme. This indicates that the topics of sustainable mobility and greener transport have always been of great importance to the European Commission. While the first FP7-funded projects focused more heavily on the research topic of Green urban mobility technologies; the focus of a large number of research initiatives moved slightly to Green aircraft technologies of the future later on, as the need for increased effort on emission reduction in aviation has become more urgent in recent years. This trend is expected to continue as the need for more environmentally friendly solutions in transport and aviation in particular is becoming a more pressing issue, and mobility research in Europe should follow to support the business needs of the sector as well as the development of a sustainable transport system.

As the 2010s is often referred to as the "decade of data revolution", it might not come as a surprise to see the Transport models harnessing the power of data research topic experiencing a rapid growth in research effort allocated to it over the past years. We expect to see this research topic continue growing in the future as data and digital transformation become even more indispensable for a sustainable and solid development of mobility in Europe.

Additionally, a framework is proposed for assessing how well the identified research topics cover the mobility challenges outlined in the CAMERA performance framework. Such a framework is designed with the idea of providing a series of metrics and aggregated statistics that can reveal further insight into the progress of mobility research in Europe with respect to the mobility challenges, as well as foster qualitative analysis by alleviating the expert-based assessment of a large quantity of information. This framework will be further developed in the last year of the CAMERA project and we

FIGURE 19
9 IDENTIFIED MOST COMMON RESEARCH TOPICS OF MOBILITY-RELEVANT PROJECTS



*cf. footnote at page. 21 and Section 3 for a discussion of these 'projects'.

expect to benefit from it by having it gently guide human experts through their analysis of mobility research projects and yielding new and interesting insights.

In this report, the framework has been employed to investigate the relationship between research topics and key performance areas (KPA) defined in the CAMERA performance framework. Preliminary results indicate that a large amount of research has been performed in the last decade on the challenges of capacity, safety and security, and intermodality. However, some areas seem still to be quite lacking, such as the challenges presented in digital transformation and the environment. In the wake of the Covid-19 pandemic and with the goal of a sustainable and rapid recovery of mobility in the years to come, increased effort needs to be put into these areas (among others). In further analysis, CAMERA will update this framework and use it to dig deeper into the level of key performance indicators (KPI) and its respective targets defined in the CAMERA performance framework in an iterative analysis that involves both a human-based and an algorithmic approach.

Further research
The CAMERA project will continue until October 2021. To improve our analysis and yield further novel insights into the status and future development of mobility research in Europe, the following actions are planned:

- Update of the current base with the latest data from H2020 projects (that are currently still missing and should be available by October 2021);
- Further correlation analysis, e.g. looking into potential confounding variables that could act as drivers of the observed characteristics of H2020 and FP7 projects;
- Fine tuning and updating the analytical framework developed so far;
- Heavier use of human experts in the loop to assess the mobility research goals at the level of KPI defined in the performance framework;
- Novel detection of gaps and bottlenecks in mobility-related research activities, relying on the identified topic and layer categorisations, and metrics and aggregated statistics obtained from data;
- Novel data visualisations and dashboards that interested parties can use to explore the data produced by CAMERA themselves and form their own insights;
- Organisation of workshops (online events) to collect input from a wider range of experts from various areas for the final analysis;
- Taking into account the impact of Covid-19, considering the novelty of the current situation and the accompanying level of uncertainty (especially when defining a final list of recommendations and areas that need more research or that might be classified as 'burning issues' for a sustained development of mobility systems in Europe).

ANNEXES

ANNEX 1

Key Performance Areas (KPAs): Keywords

The following set of keywords has been defined by experts (from the members of the CAMERA consortium team) and with the help of the objectives and indicators defined in the Performance Framework.

KPA	Expert Defined Keywords
Access and Equity	access, equity, passenger needs, travel budget, comfort, accessibility, affordability, borderless travel, human touch, social benefits, high seat-load factor, transport justice, socially compatible, passenger requirements, rural areas, reassignment of tickets, aircraft sharing, personal assistance, impaired passengers, passenger profiles, 4-hour reach, 4HD2D goal, 4 hour door-to-door goal, connected Europe, universal design, barrier-free access, inclusion, surface, fairness, delay assignment, user experience, bias, exclusion, equitable, accessible, Pareto, equal
Cost effectiveness	airspace costs, airspace use, controlled airspace, ATM, en-route costs, ANS costs, passenger-orientated costs, compensation, economics, load factor, business model, delay, cost of delay, strategic costs, hub management, network management, fleet management, crew management, cost benefit, return on investment (ROI), rate of return
Capacity	capacity, delayed passengers, en-route resilience, turnaround resilience, delay management, flow management, ATM capacity, air-traffic flow management, ATFM, communication, navigation and surveillance, CNS, information management, including system-wide information management, SWIM, improvements on-board avionics, Aviation System Block Upgrades, ASBU, operational improvement, sufficient capacity, inadequate capacity, integration mobility solutions, amending mobility solutions, capacity utilisation, infrastructure facility, congestion, disturbance, infrastructure implementation, automatic rebooking, rebooking apps, alert, cascading effect, customer care, disturbance, disruption, disruption management, journey re-configuration, network congestion management, push notifications, real time status, service delay, crisis, monitoring, reaction, recover, regulation, supply shock, technological shock, demand-supply imbalance, sector, sectorisation, train path, headway
Digitalisation and Information	digitalisation, information, real time, real-time, travel information, online, online channels, live status, on-board entertainment, on-board content, free Wi-Fi, Wi-Fi, Wi-Fi on-board, automated self-boarding, blockchain, cybersecurity, chatbot, data mining, digital element, digital experience, digital service, digital journey, home-printed tag, mixed reality, mobile service, passenger data, predictive analytics, passenger mobile app, robot, autonomous machine, self service, tracking, virtual agent, travel assistant, multi-sided platforms
(operational) Efficiency	efficiency, cost, benefit, cost benefit ratio, energy efficiency, CO2 emissions efficiency, time efficiency, estimation of cost, cost efficiency, optimal function, feasible itinerary, automation, productivity, performance, resilience, reconfiguration, automatically notified, operational efficiency, inefficiencies, P-RNAV, navigation techniques, non-optimal trajectories, Advanced Flexible Use of Airspace, AFUA, (Re-)directing, information management system, seamless information, real-time information, automated, on-the-go, real-time itinerary information, emissions per passenger, emmissions per kilometre, planned performance, systematic error, cost-effectiveness, direct route, travel itinerary, travel flow, delay, cost of delay, network, user preference, user prioritisation, slot management, regulation, ATFM delays
Environment	environment, reduction emissions, greenhouse gas emissions, environmentally friendly, CO2 efficiency, environmental footprint, CO2 emissions, GHG, noise, aircraft noise, local air quality, ground-level emissions, carbon monoxide, CO, nitrogen oxides, NOx, sulphur oxides, SOx, ozone, O3, particulate matter, PM10, PM2.5, Volatile Organic Compounds, VOC, car-exhaust emissions, airport-related emission, global emissions, pollutant, transport emissions, alternative fuels, life-cycle carbon emission, environmental impact, global warming, radiative forcing, sustainable aviation fuel (SAF), Sustainable, power-to-liquid (PtL), sun-to-liquid (StL), (liquid) hydrogen, non-CO2 effects, lifecycle analysis, climate impact, carbon footprint, alternative fuel, ACA, carbon footprint, carbon offsetting, (carbon) compensation, carbon tax, CORSIA, decarbonisation, eco-friendly, ETS, electrification, emission, emission trading system, environment-friendly, environmental awareness, flight shame, green mobility, renewable fuel, renewable diesel, biofuel, renewable aviation fuel, renewable drop-in kerosene alternative, sustainable energy system, impact assessment, direct air capture
Flexibility	flexibility, Mobility as a Service, MaaS, individualisation, personal preferences, spontaneity, on-demand, resilience, modification, options, solutions, disturbance, journey configuration, travel options, possible disturbances, recovery actions, dynamic, options, solutions, during flight, customisation, flexible ticketing, individualisation, Mobility as a Service (MaaS), on-demand, pattern recognition, passenger, personalisation, preference, passenger segment, passenger need, passenger requirement, targeted advertising, rebooking, passenger apps, resilience
Interoperability	Interoperability, Mobility as a Service (Mobility service), MaaS, one-source, single platform, single ticketing, flex ticketing, travel packages, travel devices, reliability, punctuality, simple processes, easy to use, rail and fly, intermodality, reduced process, seamless, reduced transition times, reduced queuing time, reduced waiting time, reduced security check time, transition-journey ratio, security efficiency, intermodal integration, door-to-door journeys, D2D, data sharing, connection, punctuality, buffer times, waiting times, dwelling times, baggage handling, integrated journey, passenger experience, regulations, passenger rights, flexibility
Predictability	predictability, punctuality, reliability, predict disturbances, resilience, on time, low travel time, late arrival, reliable solutions, disturbances, delay, forecasting, on-demand, cascading effect, uncertainty, risk, risk aversion, on-time performance, buffers, variability, variance, predictive analytics, robustness, absorptive, reactive
Safety	safety, safe travel, safety perception, safety feeling, fatalities, safety level, perfectly safe, accident, incident, protection measures, passenger safety measurement, risk, impact, deaths, public perception, near-miss, level bust, infringement, fail-safe, impact assessment, occurrence, procedure, weather and environmental hazards, human-centred automation, safety management system, non-professional pilots, health monitoring, aircraft system health monitoring, incident and accident investigation, safety data
Security	security, open data, personal data security, data protection, data protection law, level of security, luggage checks, security measures, security standards, humans, biometric identity, terroristic attack, terrorism, luggage screening, health screening, passenger experience, public perception, scanner, bio-scan, X-ray, residue detection, volatiles, explosives

ANNEX 2

Abbreviations

4HD2D = 4 hours door-to-door
ACARE = Advisory Council for Aeronautics Research in Europe
AI = artificial intelligence
ATC = air traffic control
ATM = air traffic management
b = billion
CAMERA = Coordination and Support Action for Mobility in Europe: Research and Assessment
CORDIS = Community Research and Development Information Service
CSA = Coordination and Support Action
DLR = Deutsches Zentrum fuer Luft- und Raumfahrt
EC = European Commission
ENG = Engine
EU = European Union
FP7 = 7th Framework Programme for Research and Technological Development
H2020 = Horizon 2020
IADP = Innovative Aircraft Demonstrator Platform
ICT = Information, Communication and Technology
ITD = Integrated Technology Demonstrator
k = thousand
KPA = key performance area
KPI = key performance indicator
LDA = latent Dirichlet allocation
LPA = Large Passenger Aircraft
MR1 = Mobility Report 1
MR2 = Mobility Report 2
MR3 = Mobility Report 3
m = million
NLP = natural language processing
REG = Regional Aircraft
SAGE = Sustainable and Green Engines
SME = Small and medium-size enterprise
SYS = System
UMAP = uniform manifold approximation and projection for dimension reduction
w/o = without
YOY = year-on-year

ANNEX 2

References

[1] Flightpath 2050, Europe's vision for aviation: maintaining global leadership and serving society's needs. European commission. Published 2011-06-07. Available at: <https://op.europa.eu/en/publication-detail/-/publication/296a9bd7-fef9-4ae8-82c4-a21ff48be673>

[2] CAMERA Performance Framework. CAMERA Consortium. Available at: <https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5bdfdd73c&appId=PPGMS>

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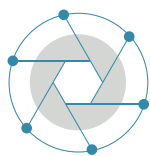
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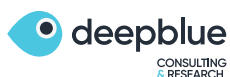
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UNIVERSITY OF
WESTMINSTER



CONTACTS

Coordinator
Innaxis
innovation@innaxis.aero

CREDITS

Author
CAMERA Consortium

Document design and editing
Deep Blue



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 769606.