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Research and innovation in smart mobility and services in Europe

An assessment based on the Transport Research and Innovation Monitoring and Information System (TRIMIS)

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Contents

Abstract

For smart mobility to be cost-efficient and ready for future needs, adequate research and innovation (R&I) in this field is necessary. This report provides a comprehensive analysis of R&I in smart mobility and services in Europe. The assessment follows the methodology developed by the European Commission's Transport Research and Innovation Monitoring and Information System (TRIMIS). The report critically assesses research by thematic area and technologies, highlighting recent developments and future needs.

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Executive summary

The report presents a comprehensive analysis of research and innovation (R&I) in smart mobility and services in Europe in the last years, focusing on European Union (EU) funded projects. It identifies progress in several thematic fields and technologies. It also highlights the relevant policy context and the market activities both in Europe and outside.

Policy context

In May 2017, the European Commission (EC) adopted the Strategic Transport Research and Innovation Agenda (STRIA) as part of the 'Europe on the Move' package (European Commission, 2017a), which highlights key transport R&I areas and priorities for clean, connected and competitive mobility. STRIA includes seven roadmaps on seven transport priority areas aiming at a more integrated and effective transport system across Europe and to make better use of innovation and new technology in transport. The STRIA roadmap for Smart Mobility and Services focuses on the assessment of emerging smart technologies and the impacts of such technologies on transport and mobility systems and services.

Smart mobility systems and services have the potential to contribute to the decarbonisation of the European transport sector. A critical link exists between new technologies, services and transport decarbonisation. However, policy and innovation efforts have focused on small changes to improve car technology rather than on integrated transport and mobility strategies. Breaking this path-dependency remains a key innovation challenge. Future transport and mobility services will need to be part of smart and sustainable city strategies to improve urban resource efficiency, decarbonisation and ensure an integrated transport system.

New mobility and transport services and systems are being created due to developments in Information and Communication Technologies (ICT)-enabled web, mobile and big data applications. Traditional automotive, public and private transport models are being challenged as new players emerge with disruptive services; blurring traditional demarcations between public transport and private mobility, including in the area of urban logistics.

In October 2019, the European Commission published the second, updated version of the STRIA roadmap on smart mobility and services, which builds on the 2017 roadmap and further develops the research and innovation strategy, in close cooperation with EU member states and industry stakeholders. The Commission will adopt a strategy for sustainable and smart mobility in 2020 that will address this challenge and tackle all emission sources.

Considering the above, the analyses included in this report are based on the targets and proposed actions set in the latest version of the roadmap and aim to support the further development of the roadmap by assessing research carried out in the specific area. The analysis identifies the current state of play and describes developments that future R&I initiatives should consider. The analysis is based on the European Commission's Transport Research and Innovation Monitoring and Information System (TRIMIS).

Key conclusions

Focusing on selected EU funded projects starting from 2012 onwards, this report presents a comprehensive analysis of R&I on smart mobility and services in Europe in the last years. The report identifies relevant researched technologies and their development phase and highlights the relevant policy context and the market activities both in Europe and outside.

Altogether, this report provides a comprehensive and up-to-date review of smart mobility and services (SMO) R&I across Europe. Although with limitations (more notably, the lack of Member State (MS) projects in the assessment), findings and insights into the current R&I status and future needs, help the STRIA Working Groups (WG) to better identify R&I activities and provides valuable information to SMO stakeholders.

Main findings

Under the 7th Framewrork Programme for Research (FP7) and the Horizon 2020 Framework Programme for Research and Innovation (H2020) about €1 bn has been invested in SMO research projects. This includes €870 m of EU funds and about €130 m of own contributions by beneficiary organisations.

A total of 1,621 unique organisations participated in FP7 and/or H2020 projects on SMO. The vast majority of the organisations involved focus on more than one transport mode, and all of them include multimodality in

their activities. Multimodal applications are the most popular followed by road transport. Rail, air and water transport have much less instances compared to the two main ones.

In many projects a large number of organisations from various countries participate. Italy is the largest beneficiary in absolute terms, followed by Germany. Even though an imbalance exists between the various countries in terms of SMO research, it does appear to be less profound when compared to the other STRIA roadmaps.

Spending on SMO research under H2020 peaked in the first quarter of 2018. Multimodal transport received the greatest interest, while waterborne transport receives the smallest amount of funds for SMO research amongst all modes.

From a text analysis on scientific research from the Scopus database, the number of publications on SMO in general has an increasing trend from year to year, with documents related to the term "smart mobility" rising from only 1 in 2010 to 150 and 127 in 2018 and 2019 respectively. Interestingly, the term "smart mobility" is mostly used in Europe (7 out of 10 countries are in the EU, with Italy being the dominant one). "Mobility as a service" is an area of research related to urban mobility and that has been trending in the last five years peaking in 2018 and 2019 with the United States (US) appearing by far the first in terms of publications, followed by Germany and the United Kingdom (UK) from Europe. The US, China and large EU countries generally occupy the first places in terms of Small and Medium Enterprise (SME)-related scientific publications. A notable case that should be highlighted is the domain of urban air (drone) mobility where the EU presence is minimal, and the US is clearly leading. On the upside, European countries are leading in the domains of soft or active mobility and the concept of living labs. Both urban air (drone) mobility and living labs are trending areas with a low number of outputs that offer opportunity for research.

The technology analysis highlights clusters that are researched in Framework Programmes (FPs) at different development phases. The concept of development phase as an indication of technology maturity has been consolidated in the TRIMIS assessment methodology and is widely used in this report. Three of the top-10 technologies have been researched over the entire development phase in FPs. E-ticketing scheme has been researched only at a research phase, something indicative of the (still) low maturity of these technologies. This is also the case for the mobility services open platform concept researched at research and validation phase. Communication (COMM) network for intelligent mobility, evidence-based road safety research, Eco-Drive app, Mobility as a Service (MaaS) model, and car-sharing platform have been also researched significantly in implementation projects.

Among the top-20 technologies, 12 are linked to road transport, 6 to multimodal transport, 1 to aviation (personal aerial transportation systems), 1 to rail (track side train presence alert) and 1 to waterborne transport (E-freight systems). Communication network for intelligent mobility has received the highest funding: almost half of it (€45 m) through two large scale H2020 projects.

Related and future JRC work

This report on research and innovation in smart mobility and services in Europe is one of the seven reports that support the implementation of the STRIA roadmaps. The TRIMIS team is consolidating and expanding the data repository to better assess R&I efforts of projects not funded by the EU or MS. As part of this effort, information will be added on technologies, patents and publications, and various other topics of interest, including on SMO. TRIMIS will continue to provide support to STRIA and, based on its research, provide recommendations to policymakers.

Quick guide

The report is structured as follows: Chapter 1 gives a brief introduction on SMO research. Chapter 2 provides the scope of the report together with a methodological background. Chapter 3 provides the state of play and Chapter 4 the policy context. Chapter 5 provides a quantitative assessment of smart mobility and services related research and innovation. Chapter 6 shows the R&I assessment, dividing smart mobility and services research in five sub-themes. Finally, Chapter 7 provides the conclusions.

1 Introduction

Smart mobility and services (SMO) have the potential to contribute to the decarbonisation of the European transport sector. A critical link exists between new technologies, services and transport decarbonisation. However, policy and innovation efforts in the past have focused to a certain extent on small changes to improve car technology rather than on integrated transport and mobility strategies. Breaking this path-dependency remains a key innovation challenge. Future transport and mobility services will need to be part of smart and sustainable city strategies to improve urban resource efficiency, decarbonisation and ensure an integrated transport system. New mobility and transport services and systems are being created due to developments in Information and Communication Technologies (ICT)-enabled web, mobile and big data applications. Traditional automotive, public and private transport models are being challenged as new players emerge with disruptive services; blurring traditional demarcations between public transport and private mobility, including in the area of urban logistics.

In this context and in order to better address current socio-economic and environmental challenges arising within a transport environment that is changing with constantly added factors of complexity, new technological developments and innovative approaches are required. Research and innovation (R&I) can provide the answer to many issues arising through this changing reality, offering novel solutions to assist the mobility of people and goods, but it has to be supported by the appropriate policy framework that will act as an enabler toward this direction.

To this aim, the European Commission (EC) adopted the Strategic Transport Research and Innovation Agenda (STRIA) in May 2017 as part of the 'Europe on the Move' package, which highlights main transport R&I areas and priorities for clean, connected and competitive mobility, covered by seven roadmaps focusing on seven thematic areas including smart mobility (European Commission, 2017a):

- Connected and automated transport (CAT);
- Transport electrification (ELT);
- Vehicle design and manufacturing (VDM);
- Low-emission alternative energy for transport (ALT);
- Network and traffic management systems (NTM);
- Smart mobility and services (SMO); and
- Transport infrastructure (INF).

Nevertheless, new transport-related systems and services introduced need to be evaluated in terms of their contribution to the overall energy and transport system sustainability. Hence, an effective monitoring and information mechanism is needed to support the implementation of STRIA. The EC Joint Research Centre (JRC) has developed the Transport Research and Innovation Monitoring and Information System (TRIMIS) in order to provide support to the implementation of STRIA through a holistic assessment of technology trends and transport R&I capacities, publish transport R&I information and data on the European transport system (Tsakalidis et al., 2018). TRIMIS received funding under the Horizon 2020 Work Programme 2016-2017 on Smart, Green and Integrated transport (European Commission, 2017b).

The 2017 SMO roadmap (European Commission, 2016) was the result of an EC initiative to jointly develop a dedicated R&I roadmap with the involvement of representatives of the European Union (EU) Member States (MS) and stakeholders from industry, academia and authorities. In October 2019, a second revised version (European Commission, 2019b) was published, building on the 2017 roadmap and further developing the R&I strategy. It is based on consultation with a wide range of European stakeholders and experts, including the outcomes of two related events, namely the Future Mobility for European Cities: Graz Forum for the EU's Strategic Transport Research and Innovation Agenda', which took place from 26-27 November 2018 in Graz, Austria, as well as the STRIA validation workshop that took place on 15 May 2019 at the EC premises in Brussels.

The revised roadmap identifies several challenges for integration of smart mobility systems and services, but also opportunities for innovation action targeting:

1. Development of sustainable and integrated smart mobility systems connecting urban and rural mobility services and promoting modal shift, sustainable land use, sufficiency in travel demand and active and light travel modes;

2. Design of effective operating models for integrating smart mobility with public transport services and zero-carbon energy systems;
3. Fair-access public digital infrastructure and mobility data management solutions;
4. Implementation of intermodality, interoperability and sector coupling;
5. Validation and integration of automated, air and virtual mobility.

For each of the above thematic areas, a package of innovation actions is proposed in order to address the linked challenges. Moreover, the priorities for implementing these actions should focus on:

1. Increasing scale, scope and leverage of innovation action;
2. Managing and governing urban, rural and regional mobility systems and services;
3. Advancing sustainable system design, interoperability and sector coupling.

The present report supports this process by assessing R&I in SMO, based on TRIMIS. It provides a comprehensive analysis of selected smart mobility-related research projects that are financed by the 7th Framework Programme for Research (FP7) and the Horizon 2020 Framework Programme for Research and Innovation (H2020). These findings can help transport stakeholders, including policymakers, regulators, transport service providers, and standardisation bodies in their respective domains. Furthermore, insights on the current status and future needs can help the responsible STRIA working group (WG) to better identify the status of R&I and potential performance indicators for the further monitoring and development of the roadmap.

2 Methodological background

The main goal of this report is to thoroughly review EU-funded projects related to smart mobility systems and services. To do so, three actions were necessary:

1. The consolidation and further development of the TRIMIS project and programme database.
2. The development of a methodology for the identification and assessment of the technologies researched within Framework Programmes (FPs).
3. The conceptual framing for the project assessment.

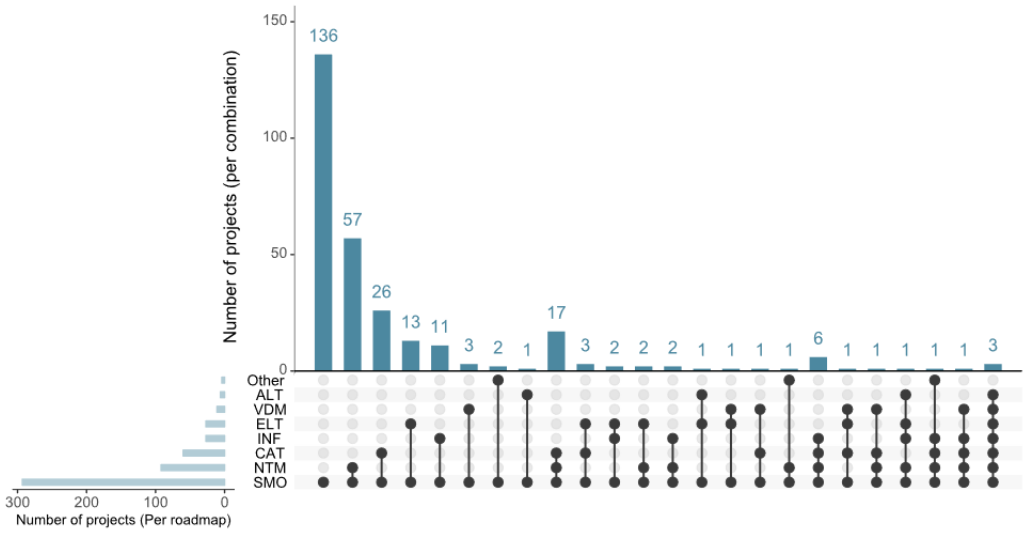
A description of these steps is provided in the following sections.

2.1 Database development and labelling

TRIMIS contains a continuously updated database of EU and MS funded programmes and projects (currently over 7,000) on transport R&I. Projects funded by the European FPs are retrieved through an automated data link with the Community Research and Development Information Service (CORDIS), while projects funded by MSs are inserted manually by national contact points, but also by TRIMIS users on a voluntary basis. Project inputs are then evaluated and labelled according to a series of criteria linked to the STRIA roadmap classification and then added to the database and published on the TRIMIS web platform (van Balen et al., 2019).

An initial step is to identify those projects that fall within the SMO roadmap. The scope of the SMO roadmap was defined by the initial STRIA roadmap and amended by the revised 2019 version. Transport experts with knowledge of the various aspects of smart mobility and with a deep understanding of all STRIA roadmaps manually labelled the projects according to the STRIA roadmap classification. Considering that many projects cover various elements within the smart mobility domain, only those projects that cover a considerable smart mobility research component in the project description were assigned to the SMO roadmap. Alternatively, a project can also be assigned to multiple roadmaps if it covers aspects also falling within the domains of other roadmaps. An overview on the extent to which SMO projects overlap with other roadmaps is presented in Figure 1. It is based on 293 FP7 and H2020 projects that were assessed and shows how often the keywords of each theme were detected (left horizontal bars) in the projects' objectives, and how often a certain combination of keywords occurred (vertical bars). The experts also assessed several other aspects of the projects, including the mode of transport and geographical focus of the project. Through discussions and inter-rater reliability assessments, the quality of the labelling was assured.

Figure 1. Overlap between smart mobility and services projects with other STRIA roadmaps.



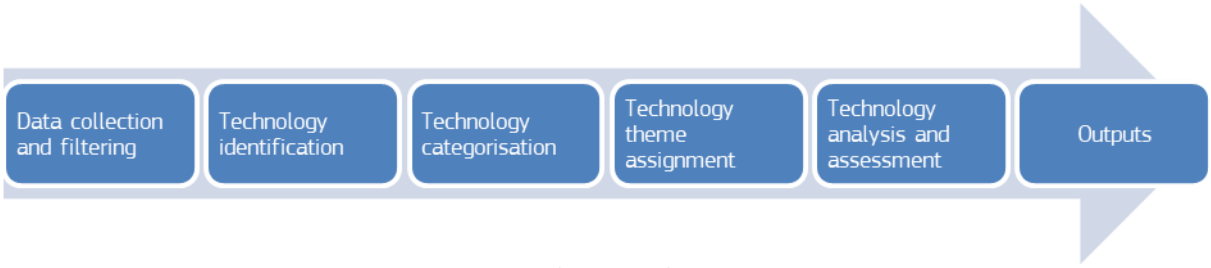
(*) Low-emission alternative energy for transport (ALT); Transport electrification (ELT); Vehicle design and manufacturing (VDM); Connected and automated transport (CAT); Smart Mobility and services (SMO), Network and traffic management systems (NTM), Transport infrastructure (INF).

Source: TRIMIS.

2.2 Identification and assessment of the technologies researched within Framework Programmes

One of the sub-tasks of TRIMIS is the creation of an inventory and regular reporting on new and emerging technologies and trends (NETT) in the transport sector (Gkoumas et al., 2018). To this aim, a framework for the taxonomy, assessment and monitoring of NETT is proposed (Gkoumas and Tsakalidis, 2019), which supports innovation management at various levels, thus providing insights to the sector's stakeholders (e.g. researchers, business operators, EU and national authorities and policymakers), while backing the current transport systems' transformation through technological advances. The TRIMIS NETT analysis currently focuses on technologies researched in European FPs, specifically FP7 and H2020 projects from the TRIMIS database. Figure 2 provides an overview of the methodology used for the technological assessment of the projects.

Figure 2. Technology assessment methodological steps.



Source: Gkoumas et al., 2019.

2,242 projects fall within the scope. Within these projects, 797 technologies were identified within 45 technology themes through a Grounded Theory approach (Glaser and Strauss, 1967). An iterative approach led to the development of a consistent taxonomy for transport technologies and technology themes.

First, the results of a study that identified technologies within European transport research projects (INTEND, 2017) were analysed by three researchers who have complementary experience in the field of transport innovation and who have individually assessed the technology list. Based on this review, the researchers came up with a standardised approach on what constituted a distinct technology and how to label them.

Following this approach, all 2,242 project descriptions were read and flagged when a technology was mentioned. This filtering exercise was required because EU-funded projects also cover non-technology focused projects. Once a technology was flagged in the project description, another researcher would validate the flagging and record the technology name.

In a next step, the full list of technologies was evaluated, and the labelling of similar technologies was aligned. The labels were inspired by existing taxonomies, such as those under the Cooperative Patent Classification (CPC, 2019).

When the technology list was established, a number of overarching technology themes was defined. Themes enable a better understanding of how technologies cluster together and which fields of research receive relatively greater interest. An extensive list of themes was created and consequently reduced to the minimum number of themes under which all technologies could still be logically placed. This process led to a total of 45 themes.

Moreover, all projects were assessed on whether they focused on SMO. If so, the associated technologies and their themes were highlighted. The funds associated with each technology were determined by linking them with the total project budget. If multiple technologies were researched in the project, the budget allocated to the technology of interest was determined by dividing the project budget by the number of associated technologies. The limitations of this attribution approach are acknowledged, but it is considered to be transparent and appropriate in the absence of technology-budget reports.

Finally, a set of metrics was established to assess the 44 technologies identified within the SMO roadmap. These metrics are intended to indicate the potential for the technology to be taken forward to application through the level of support for its development.

2.3 Project assessment

Using data from the TRIMIS database, recent programmes that have funded research in topics related to SMO have been identified. All related projects within the last two FPs, FP7 and H2020, have been included.

The sub-themes of this roadmap were selected according to the roadmap's portfolio of proposed actions that were introduced in the 2019 SMO roadmap version and were presented in Chapter 1. The sub-themes are analysed in detail in Chapter 6 under the report's R&I assessment. By adopting this clustering, it is possible to assess R&I findings focusing on specific areas of interest, give ideas on which areas have been left out until now, and compare developments. A complete table of all projects considered in this report, including the sub-themes that they are relevant to, is included in Annex 1.

2.4 Research scope

Each chapter of this report assesses SMO R&I from a complementary perspective, with a research scope and timeline that is adjusted accordingly. Table 1 highlights the approaches used in various parts of the report to facilitate understanding and interpreting the results.

Table 1. Research scope of each chapter and section.

Chapter (section)	Type of analysis	Scope
Chapter 3: State of play	Literature review	Review of trends and business initiatives
Chapter 4: Policy context	Literature review	Review of policy initiatives, focusing on the EU
Chapter 5, section 1 and 2: Quantitative project analysis	Statistical analysis	Covers FP7 and H2020 projects that commenced between 2007 and 2019
Chapter 5, section 3: Technology analysis	Statistical analysis	Covers FP7 and H2020 projects that developed a technology between 2007 and 2019
Chapter 5, section 4: Scientific output analysis	Bibliometric study	Covers publications within the SCOPUS database between 2010 and 2019
Chapter 6: Qualitative analysis	Project reviews	In-depth analysis of FP7 and H2020 projects that commenced between 2012 and 2019

3 State of play of smart mobility and services

Digitalisation and ICT developments facilitate the operation of shared and on-demand mobility services through real time information and algorithms based on big data. Mass public transport systems also benefit from the application of digital and ICT solutions to enhance operations, payment systems and user information. In turn, these technological advances allow for a further integration of the emerging mobility services with optimised public transport services and raise potential for the provision of a seamless transport system based on the mobility as a service (MaaS) concept, which may represent a real alternative to private vehicle ownership. This new mobility paradigm could lead to a reduction in the number of vehicles overall and traffic levels by increasing vehicle occupancy. This would bring significant benefits in terms of less congestion and less pollutant emissions, less need for parking space and cost reductions for users. At the same time, the likely increase in fleet vehicle turnover derived from sharing business models may facilitate the adoption of cleaner and smarter vehicle technologies such as automated, connected and alternative fuelled vehicles. With regards to electric mobility, digitalisation and ICT-based developments can facilitate the smart integration of electric vehicles into local energy grids and systems.

As of October 2016, car sharing services were operating in Europe with around 4 million members sharing over 60,000 vehicles (Shaheen et al., 2018). Car sharing services differ from traditional car rentals in that they provide users access to a car on a recurrent basis. Several business models have emerged including traditional round-trip, one-way and free-floating, peer-to-peer, and fractional ownership. A similar concept is applied to bikes, scooters and motorcycles. Bike sharing platforms, either station-based or dockless, are becoming increasingly popular in many urban areas.

Innovative mobility services are not only about sharing vehicles but also about sharing trips. The use of car-pooling for recurrent or long journeys planned in advance has grown significantly in recent years with the widespread use of specific apps boosting the number of matching options for users. However, the most obvious result of transport digitalisation is the uptake of a wide range of mobility services accessed on-demand with real time information. Ride hailing platforms are generally used for non-shared rides operating similarly to a taxi, although these increasingly incorporate shared options. When rides or trips accessed on-demand are shared between different individuals or different parties and paid separately, they are generally referred as ridesharing services. Such services may use vehicles of different capacity, from passenger cars or vans to minibuses or larger buses. The latter are sometimes named demand-responsive transport (DRT) and may offer a better alternative to fixed-route buses where there is low density of transport or when users have special needs.

Generally, shared and on-demand mobility services are still in the early stages of development as their uptake is often hampered by existing market access restrictions (e.g. limits on licenses for new mobility services). Currently, ride hailing players, mostly based in China and the United States (US), are dominating the incipient market of innovative mobility services. Europe's market, on the other hand, is much smaller and leans towards car sharing with a more fragmented landscape (Grosse-Ophoff et al., 2017).

Digital and ICT-based solutions for mass public transport are already being applied in many cities and regions around the world to optimise traffic management and traveller support. Automatic vehicle location and communication technologies can be used to improve the quality of services by optimising routing and scheduling, and by feeding real-time information into various passenger information channels. This also encompasses intelligent traffic lights and priority schemes for buses and trams.

Electronic and integrated ticketing of public transport services allow for multimodal payment with specific smart cards or, increasingly, with contactless credit cards or mobile applications. The latter open the possibility of further geographic integration, even an EU-wide payment system (European Commission, 2019c). At the same time, electronic ticketing systems can provide rich data on travel behaviour, which is increasingly used to enhance planning and operations of public transport systems.

The MaaS concept results from the convergence of multimodal journey planners, integrated and electronic ticketing, and emerging mobility services based on ICT developments. MaaS can be defined as the integration of various forms of transport services, including shared and on-demand operations, into a single information platform and a single booking and payment channel. Several MaaS schemes have emerged in recent years with different levels of integration (Kamargianni et al., 2016). Whim, initially deployed in Helsinki, and UbiGo in Goteborg are often quoted as pioneering examples of the implementation of the MaaS framework. Companies attempting to offer mobility as a service or single ticketing systems also have to manage the expectations and different business models of transport operators that they want to include in the service.

This framework demands new governance models with further collaboration between public and private agents, and appropriate data management policies.

Connected and automated vehicles will also revolutionise the transport market in many ways. Driver assistance is already incorporated in many new vehicles sold in Europe. Self-driving vehicles are currently being tested and are expected on the market between 2020 and 2030, while fully automated vehicles should arrive as of 2030 (European Parliament, 2019).

Manufacturers and suppliers are allocating a significant part of their research and development (R&D) efforts on connected and automated driving (ACEA, 2020). In the coming years, the market for connected and automated vehicles is expected to grow exponentially, creating new jobs and developing profits of up to €620 bn by 2025 for the EU automotive industry (Alonso Raposo et al., 2018).

Digitalisation and automation will also bring disruptive changes to freight services. A clear application of connected and automated driving support systems to freight is the possibility to form truck platoons by linking two or three trucks in a convoy. Truck platooning leads to significant fuel savings and less road congestion, with a more efficient use of existing road capacity. A recent roadmap by the European Automobile Manufacturers Association (ACEA) states that by 2023 it should be possible to drive across Europe on motorways with multi-brand truck platoons (ACEA, 2017).

Other developments in electronically tagged cargo, connected infrastructure and artificial intelligence (AI) applications in logistics will allow for a transition towards automated and optimised freight services both at the transport and the terminal segments of the supply chain.

While the development of drones was initially motivated by military applications, the civil use of drones or unmanned aircraft systems (UAS) is increasing year by year. According to a recent survey of drone users and manufacturers (Drone Industry Insights, 2018), surveying is by far the largest civil use of drones, followed by inspection, filming and photography, and monitoring and surveillance. These applications are already benefiting many sectors such as energy, agriculture, environmental protection and emergency management. Current uses are mainly those that can operate at very low airspace levels, within the line of sight of the remote pilot and out of populated areas. Targeted safety regulations may allow for widespread applications in the delivery of goods or even in the transport of passengers. The use of AI and automated navigation systems opens the possibility of autonomous drones with multiple additional applications. Security issues still exist, considering the substantial data exchange between UAS and ground stations. The optimal secure communication (drone-to-drone and drone-to-station) is an open research topic with different methods proposed, including the use of block-chain (Bera et al., 2020).

The European drone marketplace is promising. The total annual value in 2035 is estimated at around €10 bn and over €15 bn annually by 2050 (SESAR, 2016). Civil applications, including commercial services, are expected to generate most of this value. Nevertheless, there is a need to better define use cases in Europe, where drones could and could not be an appropriate option for deployment (Aurambout et al., 2019).

4 Policy context

4.1 Smart mobility and services in European transport policy

There is a need to substantially reduce greenhouse gas (GHG) emissions economy-wide in order to mitigate climate change. Transport emissions are a significant proportion of these (around 27%) and in 2017 were 28% above 1990 levels, despite a decline between 2008 and 2013 (EEA, 2019). Because of this, decarbonising transport systems is a key part of European policy to mitigate the effects of climate change. The transport White Paper of 2011 sets a target to reduce transport GHG emissions by about 20% (relative to 2008 levels) by 2030 and by at least 60% by 2050 (relative to 1990 levels) (European Commission, 2011). In addition, the European Green Deal sets out the objective of climate neutrality by 2050, which has as prerequisite the reduction of transport emissions (European Commission, 2019a). The transport decarbonisation challenge requires the adoption of low carbon vehicle technologies and fuels, the optimised use of transport and changes in travel behaviour in terms of significant modal shifts towards more efficient transport services. Other objectives of the White Paper are the reduction of transport-related externalities (congestion, air pollution, noise, accidents, etc.), and the achievement of a resource-efficient, affordable and accessible transport system. The Commission will adopt a strategy for sustainable and smart mobility in 2020 that will address this challenge and tackle all emission sources (European Commission, 2019a).

Digitalisation, automation and ICT-based developments applied to transport have a high potential to integrate energy, infrastructure and mobility systems and bring new paradigms of travel behaviour and transport operations. Data collected from these ICT tools have a massive potential to improve the planning of transport infrastructure and optimise the operation of mobility services. Nevertheless, depending on how they are implemented, disruptive technologies could exacerbate transport externalities. For example, the travel time savings delivered by a fully connected and automated transport system could stimulate additional road transport demand and increase trip lengths, as well as displace conventional public transport. This would lead to increased urban sprawl and congestion, without other policy actions. The use of drones for “vertical urban mobility” may lead to safety issues and excessively increase the complexity of the urban mobility system if not properly regulated. Therefore, active policies in this field should not only promote technologies and service innovations but also ensure that they contribute towards a low carbon, efficient and accessible transport systems in line with White Paper goals. European policy in this field has focused on facilitating a common market for the development and large-scale deployment of Connected and Automated Mobility (CAM) as part of the Digital Single Market (DSM) strategy (European Commission, 2019d).

The Commission’s Automated Mobility Strategy {COM(2018) 283} that was published as part of the mobility package of May 2018 (Europe on the Move III) sets the policy framework for the take-up of automated and connected mobility. As part of this strategy, the Commission will keep providing financial support to stimulate private investment in the development of technologies and infrastructure linked to automated and connected mobility. H2020 research funds in this area for 2018-2020 will focus on large scale demonstration pilot projects for passenger cars, freight transport operations and shared mobility services in urban areas, and on 5G connectivity. In addition, Connecting Europe Facility (CEF) funding will support the digitalisation of road infrastructure across the EU.

The ITS Directive {Directive 2010/40/EU} sets the legal framework for the deployment of Intelligent Transport Systems (ITS) in road transport to ensure a coordinated implementation of ITS in terms of the compatibility, interoperability and continuity of ITS solutions across the EU. The ITS Directive also sets a number of policy measures to support accessibility of EU-wide multimodal travel information for ITS users. The Commission is also currently in the process of developing a Delegated Regulation to facilitate the uptake of Cooperative Intelligent Transport Systems (C-ITS) across the EU (European Commission, 2019e).

The European policy regarding ICT-based shared and on-demand mobility services is less explicit but this issue has been embedded in many recent EU transport policy frameworks and programmes. For example, the Low Emissions Mobility Strategy {COM(2016) 501} underlines the important role of shared mobility schemes, such as bike, car-sharing and car-pooling, to reduce congestion and pollution as part of a sustainable urban mobility planning. The 2016 review of the implementation of the White Paper on Transport {SWD(2016) 226} also noted the increased use of shared mobility services under a broader trend for collaborative economy and highlighted the application of big data and ICT tools to new business models of integrated and optimised mobility services. A number of innovative mobility solutions have been tested and implemented in many European cities under the CIVITAS initiative (CIVITAS, 2020).

New business models are emerging in the field of urban mobility and giving rise to innovative mobility services, including new on-line platforms for car-pooling, car or bicycle sharing services, urban freight services or smartphone applications offering real-time analytics and traffic information (Desruelle et al., 2019). These business models have led to some legal issues. One of the main questions is whether to treat companies offering these services as IT platforms and/or transport operators, which has implications for the applicable labour law and for ensuring a level playing field with existing mobility services (e.g. taxis). In the absence of EU legislation in this area, these services are regulated by national and local authorities.

The communication on the civil use of remotely piloted aircraft systems {COM(2014) 207} sets a European strategy for the development of a common market of drone services and aircraft, and received the endorsement of the aviation community through the Riga Declaration. The strategy acknowledges that fragmented safety rules for drones based on ad hoc operational authorisations hampers the development of large-scale tests and services. Very recently, this restriction has been relaxed through the adoption of a common European regulatory framework for drones. The Commission in close cooperation with EASA adopted an Implementing Act to regulate the operations UAS in Europe and the registration of drone operators and of certified drones. The regulation will become gradually applicable within a year of publication. Safety rules will apply to all drones under a risk-based framework by establishing three categories of UAS operations ('open', 'specific' and 'certified') with different safety requirements, proportionate to the risk.

4.2 Smart mobility and services in non-European countries' policies

The potential benefits of smart mobility in terms of safety, cost, efficiency, and global competition are significant. As such, industrialised countries are competing to become forerunners of the smart mobility race. In all areas related to smart mobility, governments are challenged to adapt current regulations to disruptive changes and to promote innovation in vehicle developments and mobility services in a rapidly changing environment.

The area of connected and automated mobility is where the global race is probably more obvious. Based on a study commissioned by the United Kingdom's (UK) Society of Motor Manufacturers and Traders (SMMT) (2019), the UK scores best in a connected and automated vehicle development index taking account of enabling regulations, enabling infrastructure and market attractiveness. The US follows the UK very closely in second position, whereas Japan and China occupy the 6th and 8th position, respectively, after European countries such as Germany or the Netherlands.

In the US, testing of automated vehicles has been taking place for years led by Silicon Valley companies. A result of this is the first commercial business model with autonomous vehicles in Arizona launched by Waymo, a spinoff from technology giant Google. Nevada was the first state to authorise the operation of autonomous vehicles in 2011. Since then, 21 other states have passed legislation related to autonomous vehicles (NCSL, 2020). California, for example, has passed state level approval for driverless vehicle testing with no safety driver present. The United States Congress is discussing a bill for a Self-Drive Act, which would prevent states from enacting laws regarding the design, construction, or performance of highly automated vehicles or automated driving systems unless such laws enact standards identical to federal standards (United States Congress, 2017).

Testing with connected and autonomous vehicles is also taking place in China, Japan and Singapore. China has already adopted a plan to set up a preliminary standard system by 2020 and several roads in Beijing have been designated for autonomous driving tests. Japan has identified autonomous driving as a key innovation and has considered policies related to liabilities, driving licenses and cybersecurity laws. Singapore has introduced an amendment to the Road Traffic Act, which now recognises that motor vehicles do not require human drivers, making it the first country to widely facilitate autonomous driving at a large scale. However, a qualified safety driver is still required to take control of the vehicle in an emergency.

Shared mobility services are globally led by ride-hailing companies, which are challenging incumbent services such as taxis in many cities worldwide. In the US, market leaders Uber and Lyft have combined net revenues of $13 bn (McKinsey & Company, 2018). The Chinese company Didi has an estimated 550 million users in over 1,000 cities (Zhang, 2019) and has recently entered countries such as Brazil, Mexico, Australia and Japan. The rapid growth of ride-hailing services has taken by surprise many transportation agencies and city councils around the world. Some of the common concerns are related to working conditions and possible negative effects on congestion and air pollution, due to a lack of regulation of the vehicles used. In the US, some steps have been taken to regulate these services, ranging from per-trip fees in Chicago to caps on the number of vehicles in New York (Panktratz et al., 2018). Based on the University of California Berkeley

Carsharing Outlook 2018 (Shaheen et al., 2018), Asia is currently the largest car sharing market with around nine million users in 2016 and with an average yearly growth rate of around 100% from 2014 to 2016. In North America, the uptake has been more gradual in the last years and reached around two million users in 2016. Car sharing services are still in their early stages in Latin America and Africa.

As public transport is becoming a data-driven sector, new mobility players are emerging, and smart and integrated ticketing is being adopted in many cities worldwide, public transport authorities are increasingly adapting their governance structures and expanding their activities beyond their traditional role to become urban mobility providers (UITP, 2019). The San Francisco Municipal Transportation Agency, for example, is transforming itself into a mobility manager, with responsibilities on bike sharing, car sharing, ride sourcing, shuttles, parking and curb access (European Commission, 2018).

Regarding the use of drones, new applications for passengers and goods have been recently tested in North America and Asia. Amazon's Prime Air and Google's Project Wing drone delivery services are being tested in some locations (Vincent and Gartenberg, 2019). In addition, drone taxis have been tested in the US (Curley, 2019) and Asia with European technology (Weiss and Nicola, 2019). The increased use of drones has presented many countries with regulatory challenges (Levush, 2016). The International Civil Aviation Organisation (ICAO) has developed a UAS Toolkit (ICAO, 2020) to support the adoption of safety regulations for UAS. At the same time, most developed countries have either adopted specific legislation or implemented temporary provisions on the operation of drones (Levush, 2016). The European Commission, adopted common EU-wide rules for the technical requirements for drones (European Commission, 2019f, 2019g). The implementation of these rules across the EU will set the limits from a safety perspective, and, at the same time, will provide the framework that will help foster investment and innovation, allowing seamlessly drone business development operation. The new rules will come into force as of 1 July 2020 and include technical as well as operational requirements for drones.

5 Quantitative assessment of SMO research

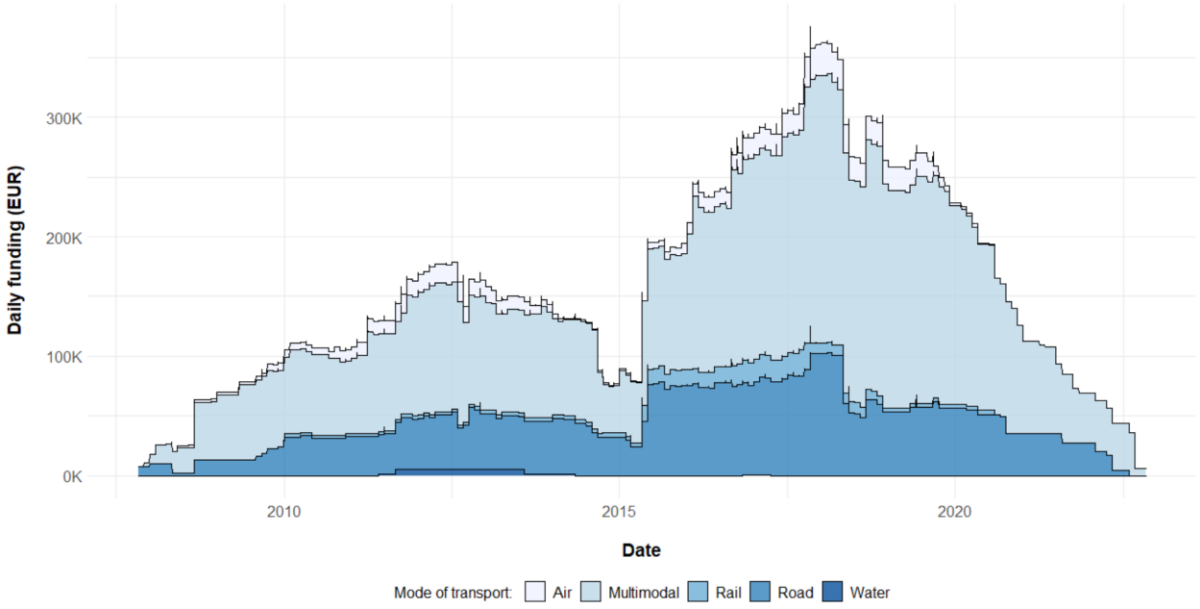
This section will display an analysis of research carried out under the EU research funding framework. The UK was still a member of the European Union in the period covered by the analyses, and therefore the UK results are included in the report. Furthermore, the UK continues to participate in programmes funded under the current 2014-2020 Multiannual Financial Framework (MFF) until their closure[1].

5.1 Framework Programmes analysis

Under FP7 and H2020 about €1 bn has been invested in SMO research projects. This includes €870 m of EU funds and about €130 m of own contributions by beneficiary organisations.

Figure 3 shows the aggregated funding statistics since 2008, assuming that project funds are spread equally through time. The figure shows an increase in funding under H2020 compared to FP7. Unlike other roadmaps, most research is focused on multimodal transport, which is indicative of the holistic approach towards modality that is propagated in the projects and roadmap as a whole. The air transport research projects are mostly focused on applications of drones in an urban context.

Figure 3. Daily research funding by transport mode.



Source: TRIMIS.

The daily funding peaked in the first quarter of 2018 at approximately €350,000. A funding forecast is also provided, based on projects that were awarded by August 2019. As there are still open H2020 calls, it can be expected that the final funding will be higher.

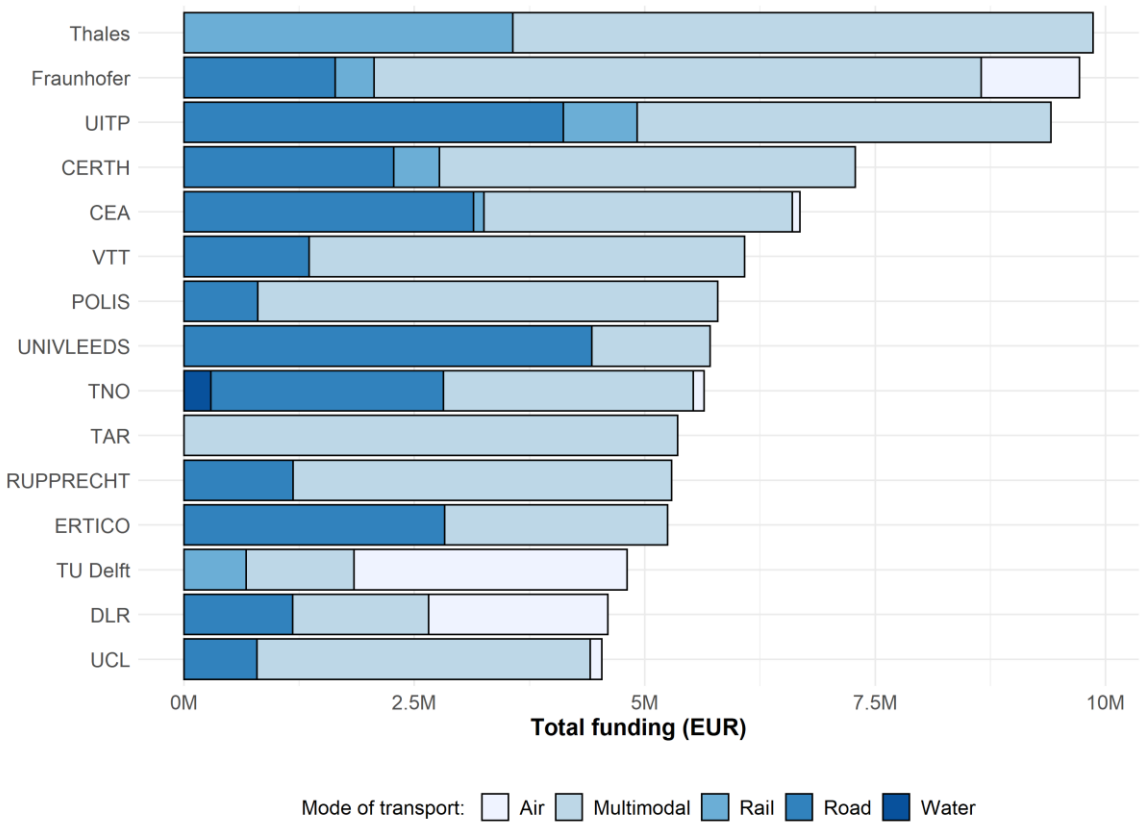
5.2 Geographical and organisation analysis

A total of 1,621 unique organisations participated in FP7 and/or H2020 projects on SMO. Figure 4 shows the top-15 beneficiaries with the total amount of funds received and their research focus in terms of transport mode.

Some organisations focus exclusively on SMO research in one mode of transport, whereas others conduct research across modes. Of the top-15 beneficiaries, 12 are active in road, 6 in rail, 15 in multimodal, 6 in air, and 1 in waterborne transport.

[1]https://www.gov.uk/government/publications/continued-uk-participation-in-eu-programmes/eu-funded-programmes-under-the-withdrawal-agreement

Figure 4. Top-15 SMO funding beneficiaries.



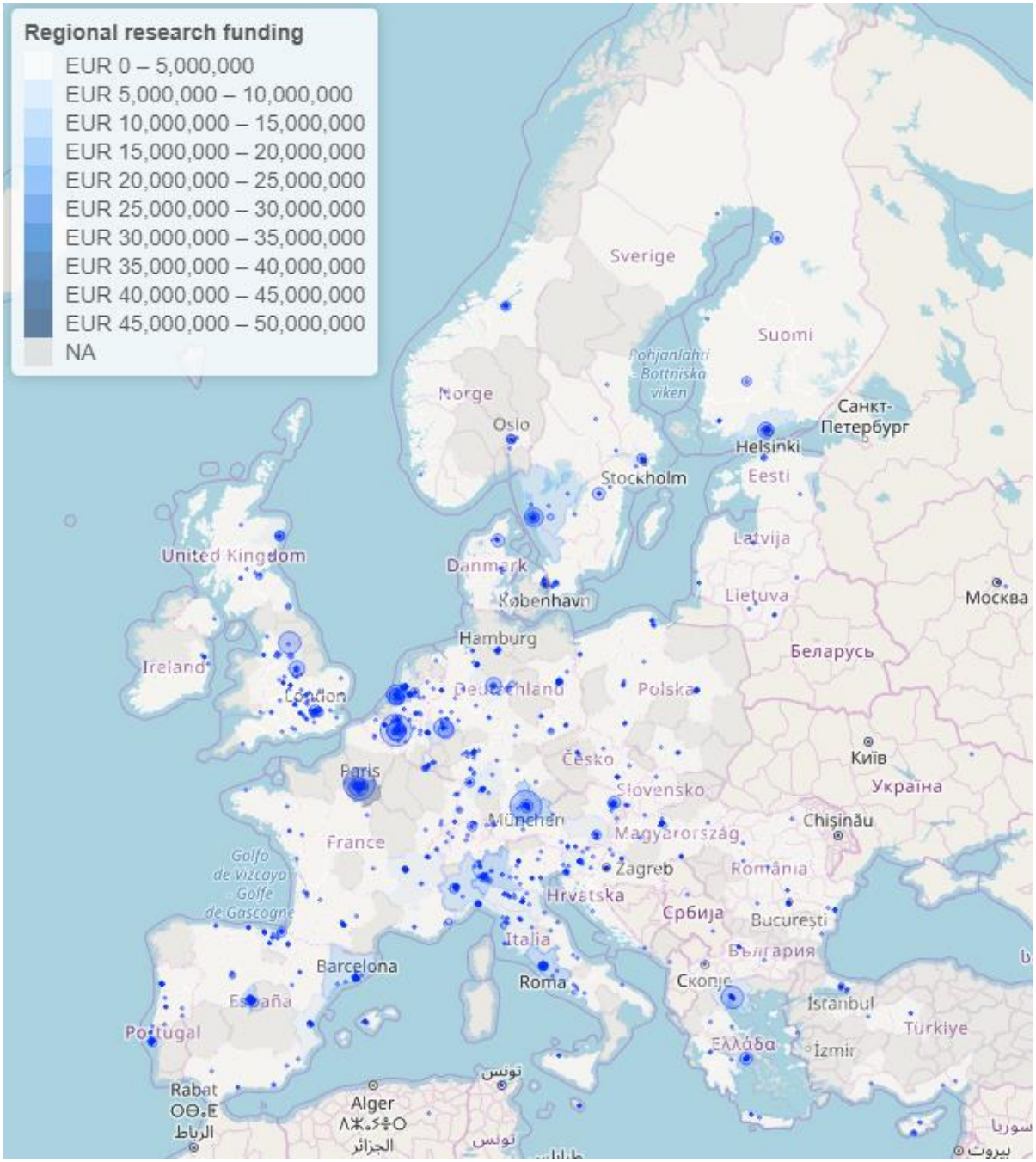
Source: TRIMIS.

The top-15 beneficiaries received approximately €96 m of funding, which is approximately 1% of the total SMO funding budget. Therefore, the funds are not very concentrated and benefit a large number of organisations.

Figure 5 provides a deeper look into the geographical spread of the funds. Several beneficiaries in Germany, France and Belgium receive a large part of the funding, as indicated by the size of the circles. In terms of number of organisations, it appears that Italy is well represented. Organisations from the EU-13 receive a smaller share of the funds.

One remark is that the spending of research funds may happen in a different location than where a beneficiary is registered. Such could happen when pilot studies occur at different sites. The map does however provide a reasonable approximation of where resources are allocated.

Figure 5. Location of SMO funding beneficiaries.

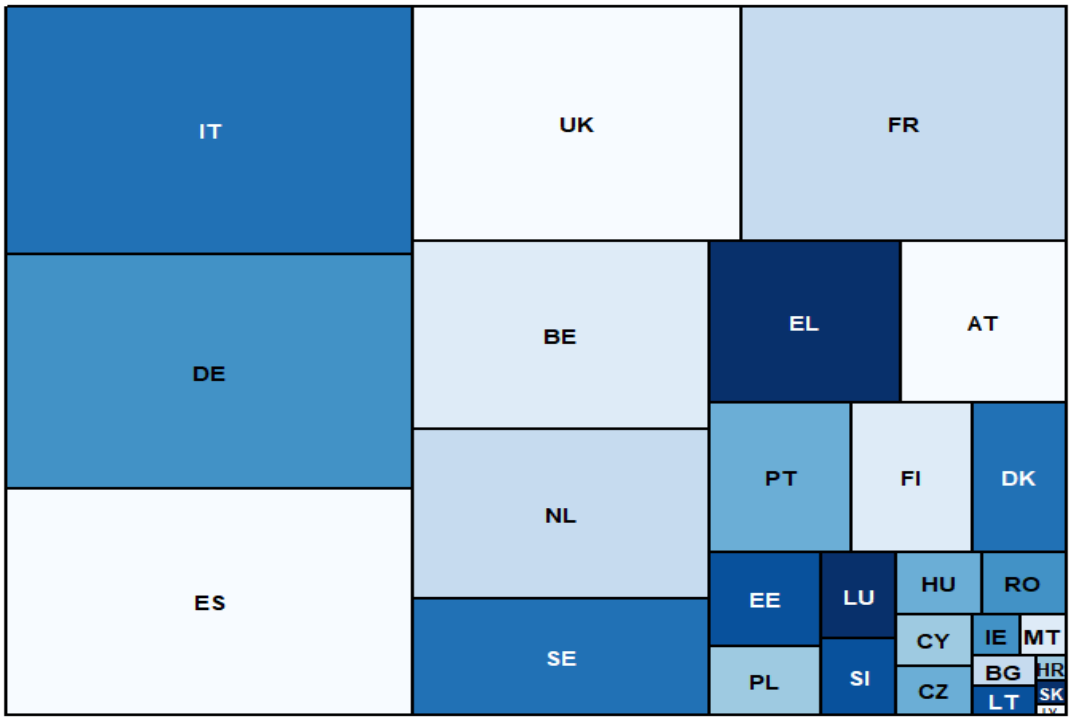


Source: TRIMIS.

5.3 Country analysis

An assessment of FP7 and H2020 SMO research in terms of funds received by country, based on the beneficiaries' addresses, shows that Italy is the largest beneficiary in absolute terms, followed by Germany (see Figure 6). Even though an imbalance exists between the various countries in terms of SMO research, it does appear to be less profound when compared to the other STRIA roadmaps.

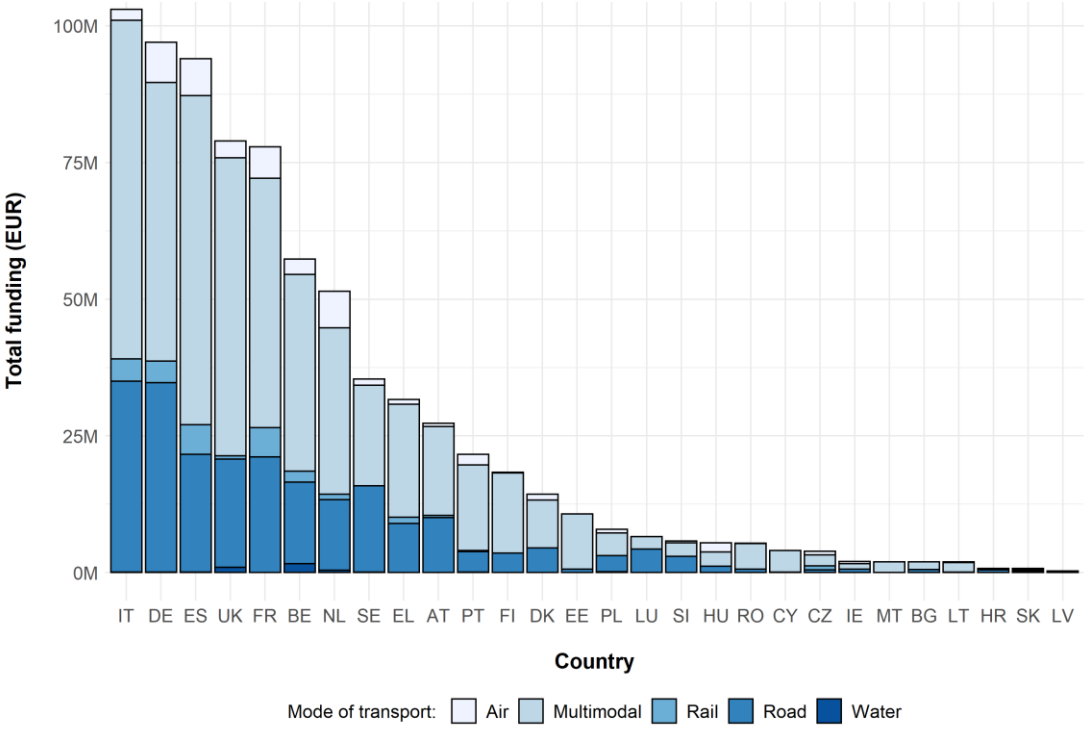
Figure 6. Shares of SMO funding by country.



Source: TRIMIS.

Figure 7 provides a more detailed overview on SMO research funding, showing the total amount of funding received per country, split by mode of transport. The figure also highlights that there are few profound differences between countries when it comes to the mode of transport that is researched.

Figure 7. SMO funding by country, including division between transport modes.



Source: TRIMIS.

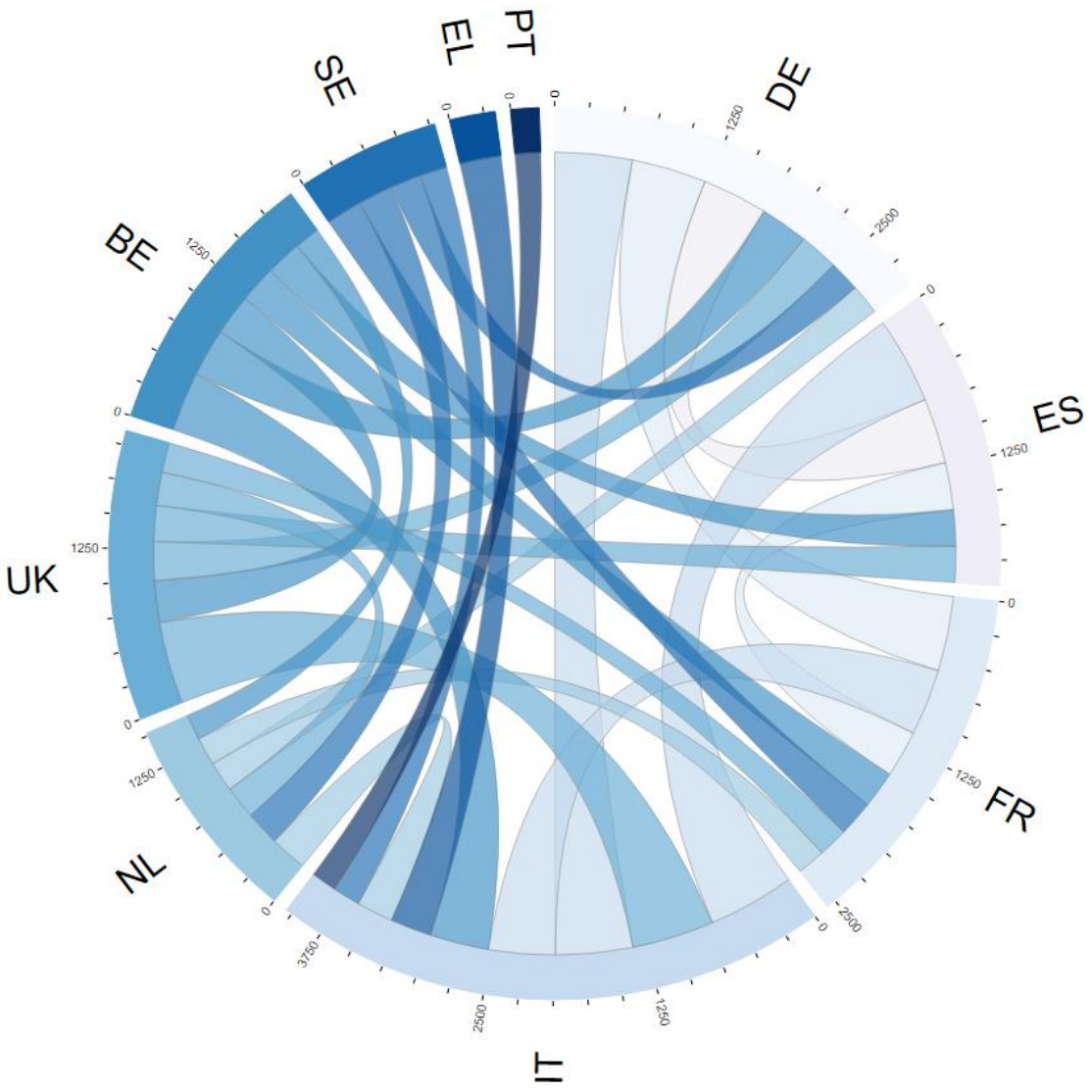
In many projects a large number of organisations from various countries participate. These collaborations can be aggregated at country level to show which countries work most often together in the field of SMO.

Figure 8 shows the most common links by highlighting those collaborations between organisations from European countries that occurred at least 250 times. This means for instance that if in a project one Spanish and two Austrian organisations collaborate, the link between Austria and Spain gains a strength of two. These counts are accumulated for all projects. The colours are indicative of the country, whereas the width of the cords is indicative of the number of collaborations.

Ten countries surpass the barrier of 250 organisational collaborations. Organisations from other countries also actively collaborate, but these ties are not visualised as they do not surpass the barrier. The analysis therefore focuses on absolute, rather than the normalised performance.

A few observations can be shared. Unsurprisingly, the larger European countries are most visible in this chart. Organisations from Belgium are also strongly present in the collaboration network, linking with many different countries. Such can be explained by the presence of many Brussels based associations in the field of transport and technology.

Figure 8. Chord diagram on collaborations in FP7 and H2020 SMO projects by country.



Source: TRIMIS.

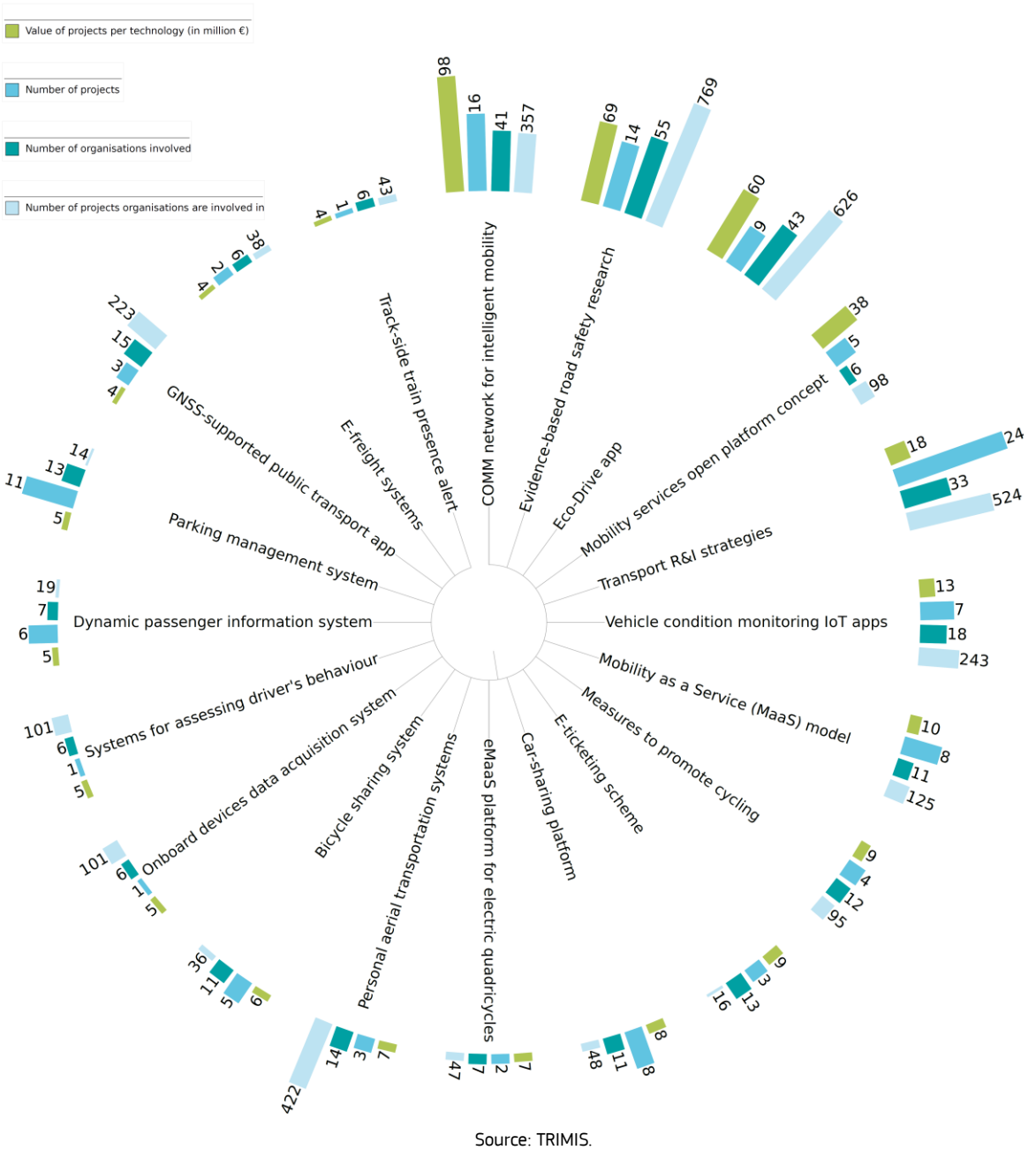
Additional analyses can be found in the dedicated TRIMIS publications on R&I capacity in smart mobility (van Balen et al., 2018) and the TRIMIS annual database assessment report (van Balen et al., 2019). The TRIMIS

online platform provides a dynamic dashboard with more information and updated insights for the users (European Commission, 2017b).

5.4 Technologies identified in the SMO roadmap

The analyses presented focus on the overall 'top-20' technologies identified in the SMO roadmap. The radial structure of Figure 9 highlights the key metrics of the 'top-20' technologies.

Figure 9. Top-20 SMO technologies in FPs.



Source: TRIMIS.

Bars not in scale. Abbreviations: COMM – Communication; MaaS – Mobility as a Service; IoT – Internet of Things; GNSS - Global Navigation Satellite System; eMaaS - Electromobility-as-a-Service. The figure is developed using the interactive tree of life (Letunic and Bork, 2016).

The metrics analysed in this case are:

— "Value of projects": the total value of all projects that have researched the technology (i.e. the total investment, by both the EU and industry, in the development of the technology);

— "Number of projects": the number of projects that have researched the technology;

— "Number of organisations involved": the number of organisations that have been involved in projects that have researched the technology;

— "Number of projects organisations are involved in": the total number of projects that the organisations (identified as having been involved in projects researching the particular technology) have been involved in.

The first two metrics highlight the combined effort that has been put into the technology, while the third and the fourth proxy the level of interest in the technology in industry and academia, indicating the available capabilities to bring the technology to market. Some highlights of these analyses follow below.

Among the top-20 technologies, 12 are linked to road transport, 6 to multimodal transport, 1 to aviation (personal aerial transportation systems), 1 to rail (track side train presence alert) and 1 to waterborne transport (E-freight systems). Communication network for intelligent mobility has received the highest funding: almost half of it (€45 m) through two large scale H2020 projects (5G-MOBIX and 5G-CARMEN).

Although with limitations linked to the approach followed for clustering technologies in technology themes and building a taxonomy, the exercise of linking several technology metrics with organisational data can be useful for identifying technology value chains, including opportunities, as well as providing indications on overspending and inefficiencies. In the future, efforts will be made to have a better coverage of technologies researched within projects, indexed in higher aggregation levels.

In addition, the technology maturity was assessed for all technologies researched within the projects. The assessment is based on the technology readiness levels (TRLs), a method for estimating the maturity of technologies during the acquisition phase of a program, developed by the US National Aeronautics and Space Administration (NASA) in the 1970's. Table 2 provides the description for each of the nine TRLs, as taken from Annex G of the Horizon 2020 work programme (2018-2020) (European Commission, 2017b) and the corresponding development phases used in TRIMIS.

Table 2. Technology readiness levels (TRLs).

TRL level	Description	TRIMIS development phase
TRL 1	Basic principles observed	Research
TRL 2	Technology concept formulated	
TRL 3	Experimental proof of concept	Validation
TRL 4	Technology validated in lab	
TRL 5	Technology validated in relevant environment	Demonstration/prototyping/pilot production
TRL 6	Technology demonstrated in relevant environment	
TRL 7	System prototype demonstration in operational environment	
TRL 8	System complete and qualified	Implementation
TRL 9	Actual system proven in operational environment	

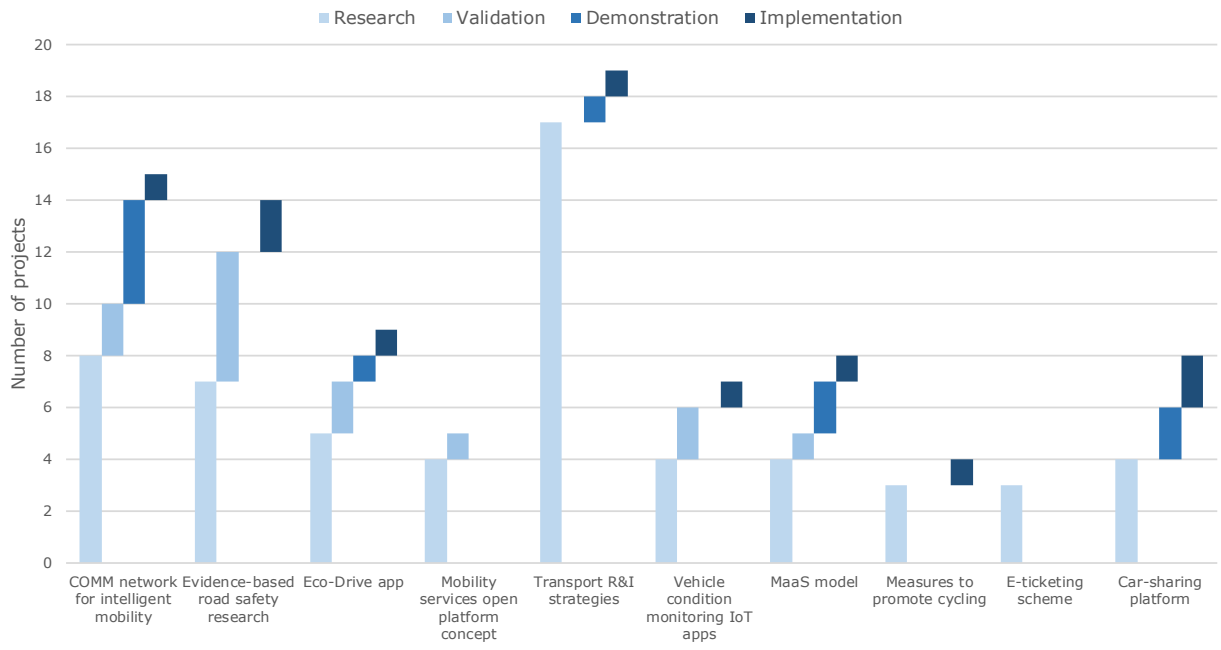
Source: Horizon 2020 work programme (2018-2020), Annex G.

The European Commission advised that EU-funded research and innovation projects should adopt the TRL scale in 2010; TRLs were then implemented for H2020 (Héder, 2017), although in practice TRLs are not consistently assigned to all H2020 projects. TRLs are based on a scale from 1 to 9, with 9 being the most mature technology.

As can be seen in Table 2, in TRIMIS, the nine TRLs have been consolidated into four development phases: research, validation, demonstration/prototyping/pilot production, and implementation. These are used to monitor and describe the maturing of each technology in a similar way to the original TRLs.

Figure 10 presents the development phases of the top-10 researched SMO technologies in FPs. Three of the top-10 technologies have been researched over the entire development phase in FPs. E-ticketing scheme has been researched only at a research phase, something indicative of the (still) low maturity of these technologies. This is also the case for mobility services open platform concept researched at research and validation phase. COMM network for intelligent mobility, evidence-based road safety research, Eco-Drive app, MaaS model, and, car-sharing platform have been researched significantly also in implementation projects.

Figure 10. Development phases of the top-10 researched SMO technologies in FPs.



Source: TRIMIS.

5.5 Analysis on scientific research

The objective of the following exercise is to mark the evolution of peer reviewed scientific publications in the area of smart mobility research in the last years, providing also a perspective beyond Europe.

The Scopus citation database for scientific research[2] has been used for the exercise. Considering the broadness of the topics addressed in the STRIA SMO roadmap and the overlapping of keywords with other STRIA roadmaps (more notably CAT and NTM), it was found more appropriate to focus on specific topics that can be linked directly to the SMO roadmap, instead of focusing on the evolution of the topics addressed within the five SMO sub-themes. It should be observed that some of the “expressions” used in the roadmap appear to be coined specifically for the roadmap or are simply forward looking. For example, the expression "individual public mobility" does not appear in the Scopus database, while a simple search using a popular web search engine provided only 186 results.

The complete list of regular expression (REGEX) used is reported in ANNEX 1, while Table 3 provides a coupling between the STRIA SMO sub-themes and some of the expressions used in this exercise. Considering the difficulty in defining REGEX and the not satisfactory results obtained, it was decided to not provide findings for the 4th sub-theme.

[2] www.scopus.com

Table 3. STRIA SMO sub-themes and scientific research terms.

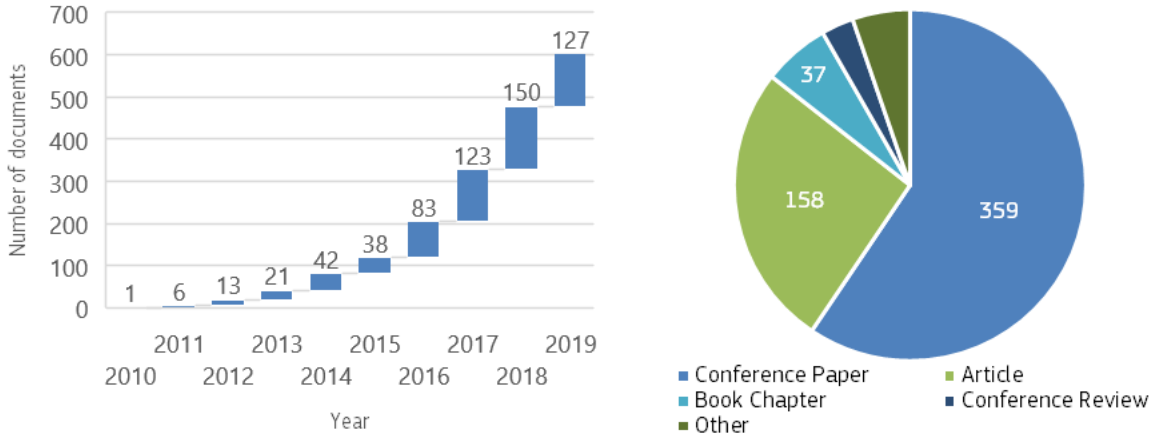
STRIA SMO sub-theme	Expressions
1. Development of sustainable and integrated smart mobility systems connecting urban and rural mobility services and promoting modal shift, sustainable land use, sufficiency in travel demand and active and light travel modes	Car-pooling Ride-sharing Car-sharing
2. Design of effective operating models for integrating smart mobility with public transport services and zero-carbon energy systems	Mobility on demand Mobility as a service
3. Fair-access public digital infrastructure and mobility data management solutions	Mobility data
4. Implementation of intermodality, interoperability and sector-coupling	Soft (and active) modes
5. Validation and integration of automated, air and virtual mobility	Drone mobility Living labs

Source: TRIMIS.

An initial search focused on the use of the term "smart mobility". Figure 11 shows the number of items published (documents) between 2010 and 2019. Considering the low number of journal papers (158), it was decided to extend the search including other sources (conference papers, book chapters etc.). Thus, the total number obtained for the entire 10-year period is 604. It should be noted that before 2010 the term "smart mobility" was almost non-existent in the database.

As it can be observed, the number of publication has increased significantly, from only 1 in 2010 to 150 and 127 in 2018 and 2019 respectively.

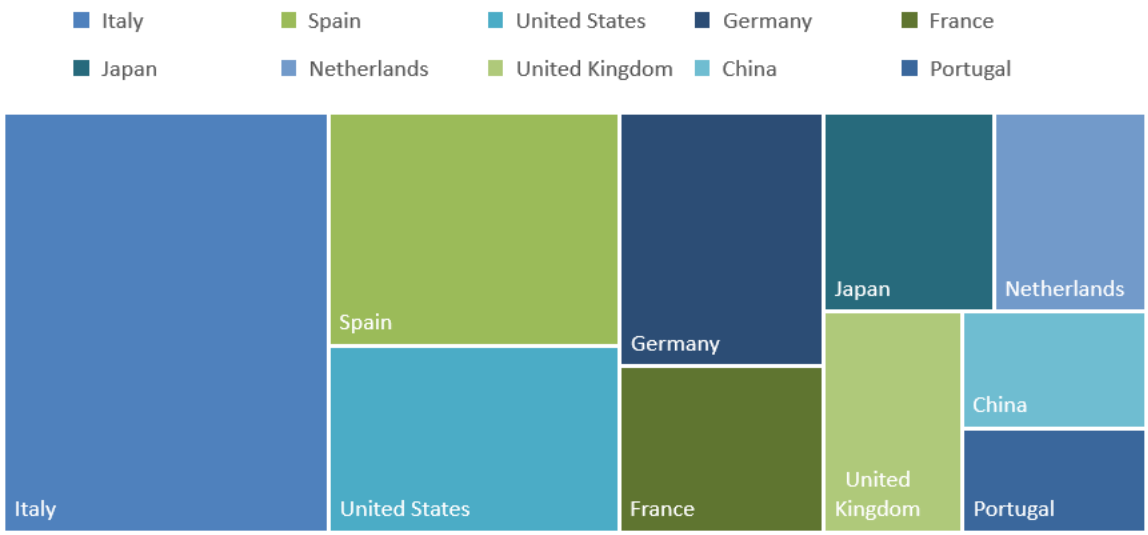
Figure 11. Overview of number of documents on Smart Mobility in the period 2010-2019 (left) and document type (right).



Source: TRIMIS elaborations based on Scopus.

Looking at the country breakdown (Figure 12) and focusing on the top-10 countries, interestingly, the term "smart mobility" is mostly used in Europe (7 out of 10 countries are in the EU, with Italy being the dominant one). This can be explained, since the term has been used extensively in the first decade of the 21st century in Europe, in the context of Smart Cities (Giffinger et al., 2007).

Figure 12. Overview of number of documents on Smart Mobility according to the country of origin in the period 2010-2019.

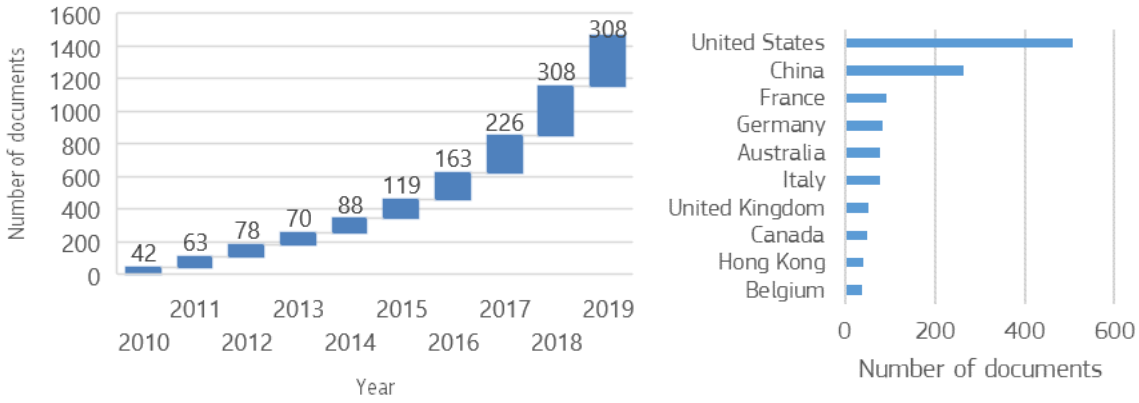


Source: TRIMIS elaborations based on Scopus.

Following these first results, the rest of the analyses focus on regular expressions representative (but not exhaustive) of the sub-themes defined in the SMO roadmap.

On carpooling and ridesharing, Figure 13 shows an increasing trend in the last five years, peaking in 2018 and 2019. The US leads the research on this topic with 506 documents since 2010, followed by China with 265 and France with 93.

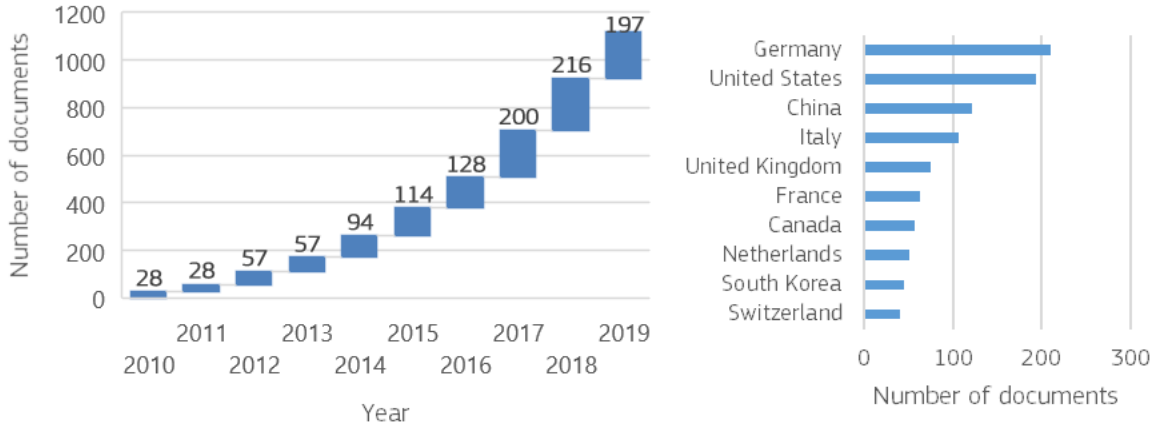
Figure 13. Number of documents on carpooling and ridesharing in the period 2010-2019 (left) and country of origin (right).



Source: TRIMIS elaborations based on Scopus.

On car-sharing, Figure 14 shows an increase in publications in the period 2017-2019. Germany leads the research on this topic with 210 documents since 2010, followed by the US with 193 and China with 122.

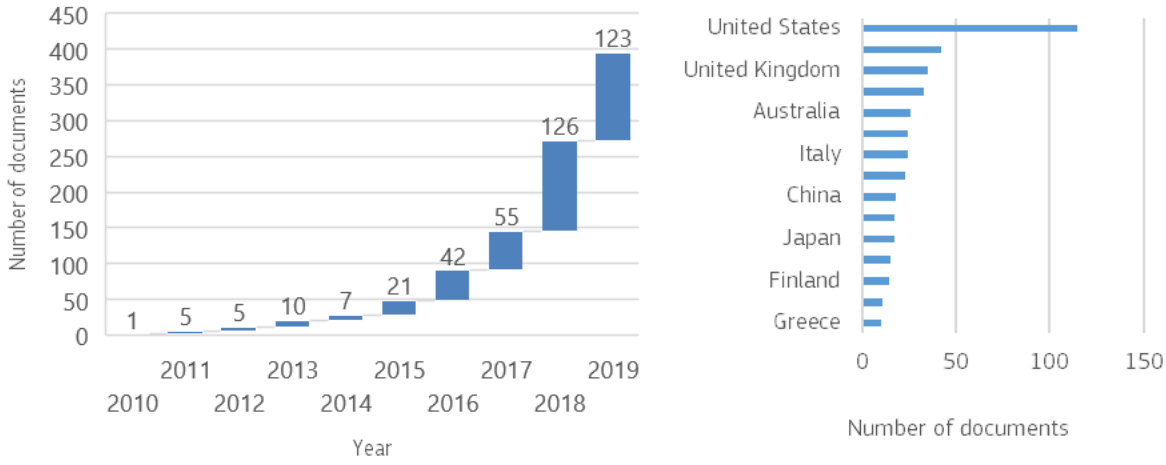
Figure 14. Number of documents on car-sharing in the period 2010-2019 (left) and country of origin (right).



Source: TRIMIS elaborations based on Scopus.

Figure 15 provides the results on Mobility as a Service (MaaS), an area of research related to urban mobility and that has been trending in the last years.

Figure 15. Number of documents on MaaS in the period 2010-2019 (left) and country of origin (right).

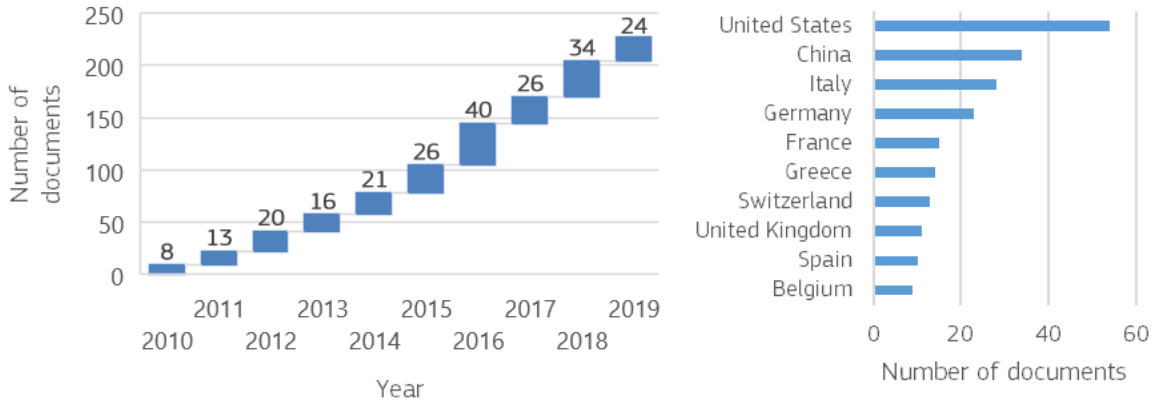


Source: TRIMIS elaborations based on Scopus.

It is interesting to observe that the terms “mobility as a service” and “mobility on demand” started to appear constantly only on 2015, with 21 references, while in 2017 this number rose to 55, to peak in 2018 and 2019 with 126 and 123 references respectively. Regarding the countries from which this research originates, the US has the highest contribution with 115 documents, 44 of which originate from the Massachusetts Institute of Technology (MIT).

Mobility data is characterised by the low number of publications and a constant average trend (Figure 16). US, China and Italy lead the research on this topic since 2010.

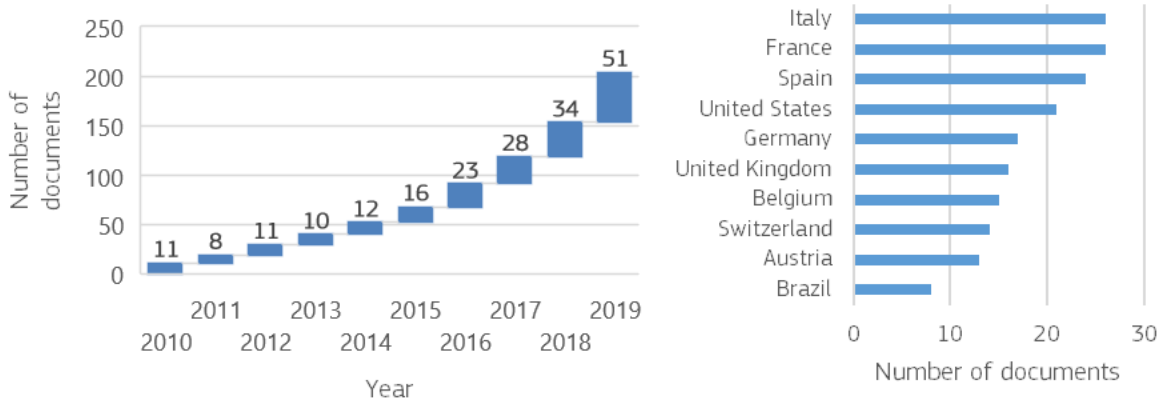
Figure 16. Number of documents on mobility data in the period 2010-2019 (left) and country of origin (right).



Source: TRIMIS elaborations based on Scopus.

On soft (and active) mobility, Figure 17 shows an increasing trend, peaking in 2019. Italy, France and Spain lead the research on this topic, while seven countries out of the top-10 are from the EU.

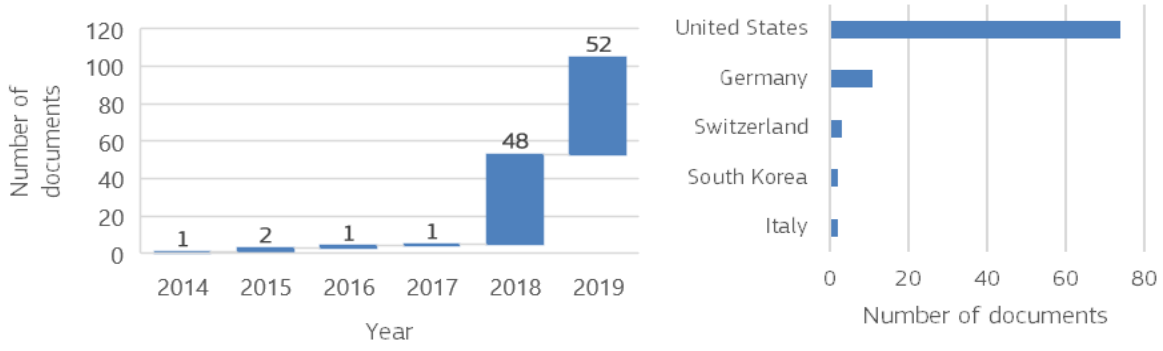
Figure 17. Number of documents on soft (or active) mobility in the period 2010-2019 (left) and country of origin (right).



Source: TRIMIS elaborations based on Scopus.

On urban air (drone) mobility, as Figure 18 suggests there were no publications in the period 2010-2013, and very few from 2014 to 2017. This changed dramatically in 2018 and 2019 with 100 publications in total. It is interesting to observe that the majority of documents originate in the US (and in particular from NASA).

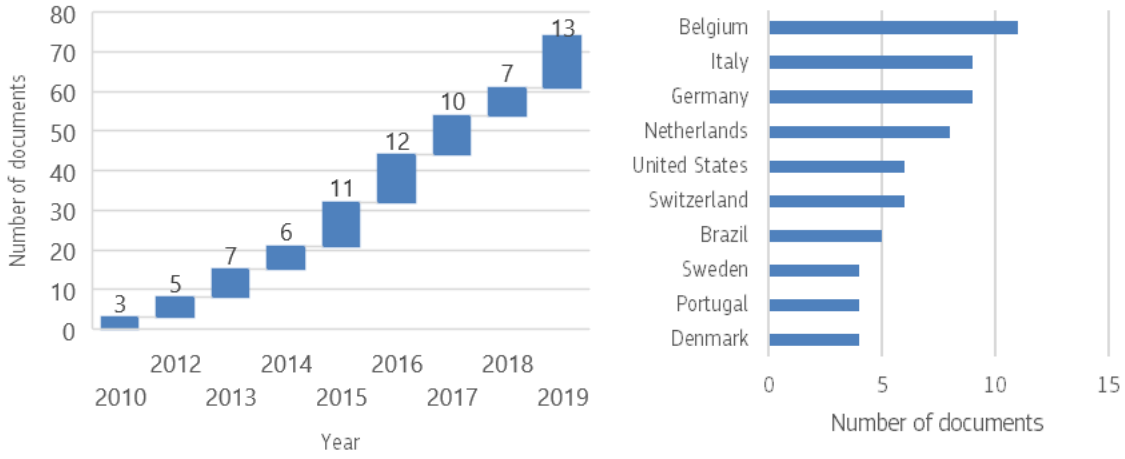
Figure 18. Number of documents on drone mobility in the period 2010-2019 (left) and country of origin (right).



Source: TRIMIS elaborations based on Scopus.

Finally, on (mobility) living labs, Figure 19 shows a generally increasing trend in the last 5 years. Most interesting is the fact that 9 out of 10 of the countries from where research originated are in Europe.

Figure 19. Number of documents on living labs in the period 2010-2019 (left) and country of origin (right).



Source: TRIMIS elaborations based on Scopus.

The result provided in this section provide a meaningful analyses research trends in smart mobility, and can be a starting point for monitoring the SMO roadmap.

6 Research and Innovation assessment

This section analyses R&I projects in the field of SMO under five key sub-themes, which cover the key areas of research being undertaken under this STRIA roadmap. The analysis provides an overview of the research being performed, its key results and the subsequent implications for future research and policy development. The sub-themes are:

1. Development of sustainable and integrated smart mobility systems connecting urban and rural mobility services and promoting modal shift, sustainable land use, sufficiency in travel demand and active and light travel modes;

This sub-theme focuses on projects which develop and implement smart mobility systems. This includes projects which improve the link between urban and rural systems, software which enhances accessibility and smart tools which improve the ease of system implementation. In addition, the sub-theme includes smart mobility solutions which promote active travel, software which supports sustainable urban mobility, technologies which support the development of intelligent freight systems and projects which support vulnerable road users.

2. Design of effective operating models for integrating smart mobility with public transport services and zero-carbon energy systems;

This sub-theme focuses on projects which design innovative operating models, combining public transport and private vehicles. The sub-theme also includes technologies which enhance the public transport user experience and passenger safety, and public transport demand response services. Projects focusing on smart city logistics, waste collection and freight consolidation are also included.

3. Fair-access public digital infrastructure and mobility data management solutions;

This sub-theme focuses on the use and management of data to improve mobility management. This includes projects which develop logistics and traffic management software, mobility data management, fair-access online reservation systems and technologies which enhance safety and navigation across the transport sector.

4. Future intermodality, interoperability and sector-coupling;

This sub-theme focuses on projects which facilitate intermodal mobility systems, across passenger and freight transport. This includes all tools aiming to encourage multimodality, technologies aiming to enhance rail transport use and interoperability and future innovative transport solutions, which aim to improve integrated mobility systems.

5. Validation and integration of automated, air and virtual mobility.

This sub-theme focuses on the development of automated mobility services, aviation and drone technologies and virtual mobility. This includes projects which develop drone traffic management and drone communication networks and surveillance. It also includes projects which have delivered smart airport concepts and air traffic management (ATM) systems. In addition, communication networks for intelligent vehicles are also covered by this sub-theme.

Each sub-theme involves the application of smart solutions to enhance mobility systems and networks. Therefore, there are interlinkages between the sub-themes and their respective objectives. In particular, there is considerable overlap between the first two sub-themes, which involve projects that aim to support the development of smart mobility systems and operating models. It is also important to note that all of the sub-themes cover multiple modes of transport.

Table 4 provides a summary of the number of projects covered by SMO, the associated total project value and the EU funding contribution, split by the five sub-themes. Project selection was initially based on European-funded projects with end dates between 2017 and 2019, which produced 117 projects. As this included few rail and drone projects, which were considered important to capture to provide a comprehensive view of the roadmap, the end date range was extended to 2015-2022. Finally, as there were no FP7 projects with end dates 2017-2019, FP7 projects with significant project value, which were completed recently (2015-2016) were also included in the analysis.

Table 4. Smart mobility and services project summary table.

Smart mobility theme	Total project value	Total EU contribution	Number of projects
Development of sustainable and integrated smart mobility systems	€82,529,810	€61,098,641	46
Design of effective operating models	€117,662,847	€71,436,966	40
Fair-access public digital infrastructure and mobility data management solutions	€26,698,045	€15,310,652	20
Future intermodality, interoperability and sector-coupling	€42,919,894	€9,716,397	13
Validation and integration of automated, air and virtual mobility	€41,844,233	€10,149,220	23

Source: TRIMIS.

It is also possible to assess the projects by funding source, as presented in Table 5. Note that, whereas a project may research multiple sub-themes (and, therefore, double counting may appear in Table 4), each project is assigned to only one funding source in Table 4.

The sub-theme analysis has focused on projects funded by the H2020 and FP7 programmes. It is worth noting that several other European-funding programmes, such as Intelligent Energy Europe and INTERREG, have funded SMO projects over the past few years. However, as displayed in Table 5, H2020 has provided the most significant amount of funding to the SMO projects covered in the analysis, followed by FP7[3].

Table 5. SMO research by parent programme summary.

Parent programme	Total project value	Total EU contribution	Number of projects
H2020	€205,925,546	€97,359,437	104
FP7	€94,988,599	€65,728,248	19
Other	€6,953,786	€1,991,999	13

Source: TRIMIS.

[3] However, data is unavailable on the project value and EU contribution of some projects in the 'Other' parent programme category. This contributes to the lower total values.

6.1 Sub-theme 1 – Development of sustainable and integrated smart mobility systems

This sub-theme covers smart mobility solutions which aim to facilitate linkages between urban and rural mobility systems. It also includes projects which aim to encourage the uptake of active travel modes (i.e. cycling and walking), and which integrate passenger and freight services. In addition, the sub-theme also covers projects aiming to foster inclusion through developing an understanding of user needs. Therefore, key technology themes under this sub-theme include, but are not limited to:

- Bicycle-sharing and car-sharing applications;
- Software supporting sustainable urban mobility;
- Software for traffic and parking management;
- Intelligent freight systems;
- Vulnerable road user technologies.

This sub-theme is important as it aims to enhance the accessibility, inclusivity and sustainability of mobility systems, through the development and implementation of large-scale smart tools and technologies.

6.1.1 Overall direction of R&I

Several areas of research and innovation have emerged as focal points in the development of smart mobility systems. Firstly, attempts to reduce car use, particularly in urban environments, form an overarching objective for several projects. For example, a number of projects focus on developing tools that facilitate the development of sustainable mobility systems, such as vehicle-sharing technologies. These projects are funded by H2020 and vary from research to implementation.

In addition, a number of projects focus on developing solutions which will increase inclusion for vulnerable road users, from research projects aiming to enhance understanding of accident causation, to the development of smart tools aiming to improve the ease of navigation for individuals with visual impairments. A number of projects also aim to improve the operation of parking systems for cars and bicycles, with the majority of these projects operating at the demonstration and implementation development phases. Finally, there is an increasing number of projects, funded by H2020, which focus on the development of sustainable urban mobility systems, and encourage the development of intelligent freight systems.

6.1.2 R&I activities

A total of 46 projects were assigned to this sub-theme, with the majority funded by H2020, as highlighted in Table 6.

Table 6. Sub-theme 1 research by parent programme summary.

Parent programme	Total project value	Total EU contribution	Number of projects
H2020	€54,369,692	€41,705,477	32
FP7	€24,176,120	€17,401,165	5
Other	€3,983,998	€1,991,999	9

Source: TRIMIS.

To provide a more detailed analysis, some key projects were selected to demonstrate the core areas of research undertaken in the SMO roadmap. The projects have been selected based on one or more of the following criteria: available project results; recent project completion date and high project value.

— SocialCar (2015-2018) is an H2020-funded project, which developed an ITS with an innovative approach to transport demand management. The primary objective of the project was to develop an information-sharing network for car-pooling, which was to be integrated into existing transport systems. The project aimed to contribute to reducing congestion, validate green driving support systems and identify an appropriate big data management architecture for integrating mobility data. Finally, the project aimed to develop an open city-based repository of traffic and public transport data.

— VRUITS (2013-2016) is a project funded by FP7-TRANSPORT, which aimed to improve the safety and mobility of vulnerable road users (VRUs), through the development of ITS applications. The project assessed the societal impacts of several ITSs, providing evidence-based recommendations for how the experiences of VRUs could be better integrated into ITSs and how human machine interfaces (HMIs) could be better adapted to meet the needs of VRUs.

— 2MOVE2 (2012-2016) is a project funded by FP7-TRANSPORT, which aimed to enhance urban mobility by developing sustainable urban transport systems in the participating European cities. The project involved the development and implementation of similar measures in four cities to enable comparison of the effectiveness of measures in cities with different features. The measures selected were also easily transferable to small and medium-sized towns. The key measures included the deployment of ITS for traffic management, sustainable urban transport planning and ITSs for personal and freight applications.

— InDeV (2015-2018) is an H2020-funded project, which aimed to provide an in-depth understanding of road accident causation. The primary objective of the analysis was to develop a toolbox for the analysis of accident causation for VRUs. This was based on accident databases, in-depth accident investigations, surrogate safety indicators, self-reported accidents and behavioural data. The approach aimed to reveal the causational factors by focusing on the process of accident development.

— XCYCLE (2015-2018) is an H2020-funded project, which aimed to develop a solution to improve the treatment of cyclists in traffic, to enhance the safety and comfort of cyclists and therefore, increase active travel uptake. The project aimed to develop technologies to improve the active and passive detection of cyclists in traffic, systems for informing vehicles and cyclists of hazards at junctions and cooperative systems for reducing accidents. XCYCLE also aimed to develop and test a demonstration bicycle with cooperative technology.

— EMPOWER (2015-2018) is an H2020-funded project, which aimed to reduce the use of conventionally-fuelled vehicles (CFVs) in cities, through encouraging behavioural change. The project aimed to reduce the use of CFVs through encouraging modal shift, promoting vehicle-sharing and reducing the demand of CFVs generally. The EMPOWER concept will enable city stakeholders to choose policy options which will enable them to achieve desired impacts. The project aimed to produce the EMPOWER toolkit and to enable industry stakeholders and policymakers to implement mobility measures, which will contribute to a fall in CFV use.

— FLOW (2015-2018) is an H2020-funded project, which aimed to engender a paradigm shift in urban environments, through encouraging the uptake of non-motorised modes to tackle congestion. To achieve this, FLOW aimed to develop a user-friendly methodology for evaluating the ability of walking and

cycling measures to reduce congestion. The methodology aimed to include the development of assessment tools to enable cities to evaluate the effects of walking and cycling measures.

— VitalNodes (2017-2019) is an H2020-funded project, which aimed to deliver evidence-based recommendations for more cost-effective and sustainable integration of all 88 urban nodes in the TEN-T network corridors, addressing specifically the multimodal and intermodal connection between long-distance and last-mile freight logistics. VitalNodes aimed to build a lasting network of European, national and regional networks, through applying a proven approach for the optimisation of urban areas from the perspective of multimodal transport infrastructure and spatial development.

6.1.3 Achievements

Several projects have improved upon the current state-of-the-art in SMO. The results and achievements of these projects are presented below.

— SocialCar developed a user-oriented platform for planning and booking, as well as an integrated payment system, combining carpooling and other on-demand services with public transport. SocialCar has been tested in 10 European sites, and the service has been released as RideMyRoute via Google Play and the iOS app store. The tool provides both technological innovation, by enabling electronic payment for transport, and economic innovation, by developing new mobility service models. Therefore, the project developed from an initial research development phase, to implementation, with the associated app now available to download.

— After assessing 10 road safety innovations, VRUITS identified the measures which have been most successful in increasing the safety and comfort of VRUs. The project found that the focus on vehicle and infrastructure design in policy and research has resulted in the needs of VRUs being dismissed. A comprehensive cost-benefit analysis was completed to assess the societal impacts of various ITS approaches. The project recommended clear actions for policymakers and industry, presenting seven systems which significantly enhanced the safety, mobility and comfort of VRUs. Further large-scale testing is still required; however, the test cities are taking action forward, with a pilot in Spain resulting in the creation of 'SafeCross', which helps pedestrians with reduced mobility to cross roads safely. Therefore, this project has moved from an initial validation development phase, to demonstration.

— Across all four participating cities (Brno, Tel Aviv, Malaga and Stuttgart), 2MOVE2 partners developed 23 sustainable urban mobility measures. In Stuttgart, the carpooling system was upgraded, resulting in an increase in the demand for car sharing. In addition, a recommended road network for heavy goods vehicles (HGVs) was also developed, which aimed to reduce the air and noise pollution experienced by VRUs. In Malaga, guidelines were developed for the implementation of a dynamic air quality monitoring system. In Brno, analysis was conducted to evaluate the capacity to introduce both a demand-responsive bus service and develop electric mini-buses. In Tel Aviv, the effectiveness of non-financial incentives to encourage the use of sustainable transport modes was tested. In all of the cities, the measures tested and implemented enabled the cities to understand how to enhance engagement with sustainable urban mobility, highlighting where gaps in infrastructure and policy still exist and furthering the understanding of user needs and behaviour.

— The primary outcome of InDeV was the development of a handbook, which outlines effective methods for analysing safety and the benefits and limitations of these methods. One of the key learnings was that there is a need to reduce reliance on police data, which the project found that largely underestimated the number of accidents involving pedestrians and cyclists across Europe. InDeV also developed a unique dataset, recording more than 10,000 interactions between motorised vehicles and cyclists/pedestrians. Although the project has been finalised, the intention is to enable future projects to build upon the tools and knowledge developed in InDeV. Some aspects of the project are considered non-technologies, such as the development of the handbook. Therefore, development phases are less relevant in this case. However, the development of the database has moved beyond the initial research phase, enabling future projects to make use of the collation of data.

— XCYCLE developed technologies aimed at improving the safety and comfort of cyclists. An in-vehicle detection system and a system designed to enable risk avoidance were developed. In addition, a demonstration bicycle with cooperative technology was developed. All of the solutions were tested and verified through use cases in Braunschweig. The project contributed to the development of advanced measures to reduce the number of accidents involving cyclists. The tools developed by this project will

contribute to the development of the European Road Safety Observatory (ERSO), through providing additional knowledge and specialist information to add to the portal.

— EMPOWER aimed to gather and consolidate evidence on the use of incentives and social innovation to reduce the use of CFVs. Through the use of smartphone applications, services were designed to deliver tailored incentives, also incorporating mobility tracking software, to develop an understanding of an individual's personal mobility behaviour. EMPOWER delivered 22 project outputs, from reviewing international business models to developing a behavioural model and conducting city trials. The EMPOWER toolkit was launched, bringing together guidelines, case studies and tools to enable key stakeholders to implement initiatives to reduce CFV use. The project has moved from an initial research phase, to demonstration, testing the validated solutions in city trials.

— FLOW made a significant contribution to improving the knowledge base around walking and cycling as congestion-reducing measures. The project developed assessment tools to facilitate the evaluation of the effects of walking and cycling measures. The tools included a congestion impact assessment, which comprised an assessment of socio-economic impacts, an assessment of soft measures, an assessment of congestion (based on key performance indicators) and a cost benefit analysis. The tools also included traffic modelling. Existing modelling software was calibrated and customised in FLOW partner cities, to analyse the relationship of cyclist and pedestrian movements to congestion. FLOW broadened the focus of transport planning by developing a multimodal definition of congestion that includes also walking and cycling. This methodology allows transport planning professionals to analyse and compare the congestion reduction impact of traditional car-focused measures with walking and cycling measures.

— VitalNodes aimed to deliver a self-sustaining network of experts, end-users and case-owners. So far, the project has organised workshops across a number of different urban nodes, which has provided the European Commission and urban nodes with clear insights into the research and funding needs required to stimulate the sustainable integration of urban nodes into the TEN-T network. The project also developed a proven Vital Nodes approach for future cases, composed of an enhanced toolbox, an appraisal methodology and a deployment strategy. The project has helped to address some of the issues surrounding efficient and sustainable solutions for intermodal urban freight, and long-distance and last-mile delivery.

6.1.4 Implications for future research

To date, the majority of large-scale SMO projects have involved research of innovative technologies. Therefore, many of the projects have set the foundation for further development, with validation, demonstration and implementation at a larger scale still necessary. Under this sub-theme, the development of technologies for VRUs, software to support active travel uptake and sustainable mobility, and tools to enhance intelligent freight systems are all still relevant areas of research. Therefore, building upon projects that have since finished, such as EMPOWER and InDeV, will enable projects to develop beyond the initial research development phases, to reach demonstration and implementation.

As many projects are developing solutions to similar issues, there is greater scope to enhance cohesion and knowledge-sharing between projects. In the area of active travel, this is particularly applicable, with many projects aiming to enhance the uptake of cycling in cities, such as XCYCLE and FLOW.

SocialCar provided a pivotal development in carpooling technologies, demonstrating the use case for carpooling in several cities in Europe. Building on the key learnings of this project, this solution could be scaled to extend to other cities across Europe.

2MOVE2 provides a host of developments across sustainable transport, from carpooling to a demand-responsive bus service. This project provides useful insights on the acceptance of sustainable urban mobility measures across a number of cities, offering invaluable evidence for cities around Europe in the process of developing their sustainable urban mobility plans (SUMPs).

VitalNodes provides initial insights into the integration of urban nodes into the broader TEN-T network. The project notes the need for further research into the deployment of innovative solutions in urban areas, to facilitate efficient and effective integration of urban nodes into TEN-T corridors.

6.1.5 Implications for future policy development

The projects completed under this sub-theme offer significant innovations in the context of safer, low carbon mobility systems. As outlined in the policy context, European policy on shared and on-demand mobility

services has yet to be fully developed. Therefore, as innovations continue to occur in this area, further policy development may be necessary. However, there is not a complete gap in the policy area, with the Low Emissions Mobility Strategy highlighting the importance of shared mobility schemes, such as car-pooling services, in relation to sustainable urban mobility. Where ITS technologies are proven to be beneficial, their implementation under the ITS Directive (2010/40/EU) could be facilitated.

The VRUITS project offers clear actions for policymakers on improving mobility systems to account for vulnerable road users. This is a key policy area which could benefit from further development, taking lessons from VRUITS and similar projects, to enhance the safety and comfort of VRUs. Such findings might influence future amendments to the Infrastructure Safety Directive (2008/96/EC), for example.

6.2 Sub-theme 2 – Design of effective operating models

This sub-theme covers smart mobility solutions, which aim to develop sustainable and accessible mobility operating models. This sub-theme applies to both passenger and freight transport (largely road and rail), with a focus on urban areas.

Therefore, key technology themes under this sub-theme include, but are not limited to:

- Public transport demand response services;
- Tools to improve passenger safety;
- Tools for sustainable city logistics;
- Waste collection management;
- Urban freight consolidation;
- Smart cities.

This sub-theme is important as it aims to enhance the efficiency and effectiveness of public transport and city logistics through the development and implementation of smart operating models and tools which support this growth.

6.2.1 Overall direction of R&I

The design and implementation of operating models has witnessed significant innovation over the past decade, particularly within urban landscapes. As cities aim to transform mobility systems into low carbon networks, research has focused on designing operating models which are tailored to low carbon systems, as well as having the capacity to integrate public and private transport. As such, many projects have focused on designing models which offer integrated multimodal solutions for passenger transport. From the selected projects, there is a clear focus on improving the user experience for travelling individuals, whether through public transport, private hire vehicles or flights.

In addition, several projects have focused on developing operating models for freight transport, facilitating sustainable city logistics and freight consolidation. Overarching these projects is a movement towards the

development of smart cities, with smart mobility operating models providing a key foundation to their development. Approximately half of the selected projects are in the research development phase, suggesting that research in the field is still developing, particularly in regard to software supporting sustainable mobility and multimodality.

6.2.2 R&I activities

A total of 40 projects were assigned to this sub-theme, with the majority funded by H2020, as highlighted in Table 7.

Table 7. Sub-theme 2 research by parent programme summary.

Parent programme	Total project value	Total EU contribution	Number of projects
H2020	€63,402,832	€37,117,173	27
FP7	€51,290,227	€34,319,793	10
Other	€2,969,788	€0[4]	3

Source: TRIMIS.

To provide a more detailed assessment, a number of key projects have been selected to demonstrate the core areas of research undertaken under this sub-theme. The projects have been selected based on one or more of the following criteria: available project results; recent project completion date and high project value.

- REMOURBAN (2015-2019) is an H2020-funded project, which aims to develop and validate a sustainable urban regeneration model, drawing upon its application to three cities (Valladolid, Spain; Nottingham, UK and Tepebasi, Turkey). The model integrates mobility, energy and information and communications technology, to enhance the sustainability of urban mobility systems. The model will focus on the needs of citizens to ensure that the key stakeholders involved in the development of smart cities are accounted for. Following application in the three initial cities, the applicability of the model to other cities will be tested, through assessing the relevance of the model in two additional cities (Seraing, Belgium and Miskolc, Hungary).
- SMARTFUSION (2012-2015) is a project funded by FP7-TRANSPORT, which aimed to develop and demonstrate transport innovations in urban freight. The project aimed to evaluate the feasibility of integrating electric and hybrid vehicles into the logistics sector, combining vehicle technologies with smart systems to develop urban consolidation centres and telematics networks. The project also involved the development of a 'Smart Urban Designer Tool', to enable other cities and companies to assess the costs and benefits of implementing smart logistics technologies.
- OPTICITIES (2013-2016) is a project funded by FP7-TRANSPORT, which aimed to enhance the connectivity of transport networks, through drawing upon public-private partnerships to develop ITSs. The project developed data-centric decision-support tools, to facilitate mobility management, as well as generating a tool to enable fleet operators to optimise their deliveries in cities. To facilitate these smart tools, the project also developed a new governance scheme, bringing together the private and public sector to enhance the capability of urban mobility systems.
- ETC (2015-2017) is an H2020-funded project developed to enable key stakeholders in the European travel sector to develop account-based travelling. The European Travellers Club (ETC) is a programme which puts travellers at the heart of the scheme, ensuring that user experiences are prioritised. The system has been designed to enable easy integration into existing e-ticketing infrastructure, travel planning and booking tools. The solutions enable smart phone integration and the governance structure is designed to ensure interoperability.
- BUSUP (2017-2018) is an H2020-funded project, which aims to enable passengers to book on-demand crowd-sourced buses. The project developed an app and web platform to enable users to develop their

[4] Data on the EU contribution to these projects is not available via TRIMIS or via the project websites. Therefore, the value is listed as €0.

own routes for leisure or commuting purposes. BUSUP aims to provide a service in areas where public transport is limited, providing a more sustainable and cost-effective option than using a conventionally-fuelled vehicle. The app draws on AI algorithms to provide a comprehensive solution, which offers optimal routes for passengers.

6.2.3 Achievements

- REMOURBAN is still underway; however, the impacts of the project to date are available. Currently, REMOURBAN has resulted in a 50% reduction in CO_2 emissions annually in the current lighthouse cities (Valladolid, Nottingham and Tepebasi). In addition, the impact of human activities on energy use has been reduced, through reducing the building energy demand by 40%, and increasing the uptake of low carbon mobility solutions by 5% across the lighthouse cities. A total of 14,620 citizens have been involved in the demonstrations in the three lighthouse cities. The project has effectively delivered initiatives to encourage the development of low carbon energy systems in all of these cities. For example, the municipality staff in Valladolid are now equipped with a fleet of 13 electric vehicles, and 19 charging points located around Valladolid, to enable municipality staff and private electric vehicle owners to charge their vehicles.
- SMARTFUSION worked on reducing emissions and congestion associated with freight transport. The project worked to support transformation in the electric vehicle industry through enabling developments in intelligent planning systems for freight deliveries. Through the use of three demonstration regions (Berlin, Lombardy and Newcastle), SMARTFUSION was able to apply sustainable vehicle technologies in city contexts. This included using trip planning software tailored to clean vehicles. The project developed new system architecture for low carbon urban logistics and a new concept for hybrid trucks and buses. The systems and technologies developed under the project were tested and proved to be technically and commercially viable.
- OPTICITIES developed and tested a range of urban ITS solutions in Grand Lyon Métropole, Birmingham, Gothenburg, Madrid, Turin and Wroclaw. The key achievements of the project include the development of an interface that enabled apps for multimodal travel to connect with in-vehicle navigation systems, the development of an open ITS architecture and system and the creation of a model tracking urban multimodal data. In addition, real-time carpooling, road works management systems and urban navigations were also developed by the OPTICITIES partners.
- The European Travellers Club (ETC) completed a range of pilots to demonstrate account-based ticketing in action. For example, the ETC was used in Park & Ride scheme in Luxembourg for parking and earning loyalty points. The European Travel Lab was set up in Amersfoort train station in the Netherlands simulating the ETC experience through the 'Travel' app. Through the app, individuals can charge their electric vehicles, purchase tickets, park vehicles and experience multimodal travel.
- Following testing with bus operators and passengers in Barcelona, BUSUP has extended its reach, providing a number of tailored routes to passengers. Through downloading the BUSUP app, individuals can design their own route, receive a quote and rent their own bus to complete their journey. The app enables split payment between passengers, so that the cost of renting the bus is easily divided between passengers. In addition, the service provides shared bus routes for organisations, enabling companies to engage in more sustainable travel solutions. This also includes route and billing management. So far, the app has engaged over 90 companies in over 3,880 trips, saving around 422 kg of CO_2.

6.2.4 Implications for future research

This sub-theme covers a large number of projects with a specific focus on public transport and the development of operating models to enhance the safety and energy efficiency of mobility networks. The majority of projects are at the early research stage, with several also at the demonstration and implementation phases.

The selected projects represent some of the key areas researched under this broad sub-theme. ETC offers an insight into the growing field of account-based traveling and has developed an app which offers a broad range of services to encourage the uptake of low carbon transport. Both ETC and OPTICITIES have tested their solutions in a number of cities, paving the way for future research into ITS solutions for passengers. Similarly, SMARTFUSION has also tested its technology in a number of cities, providing trip planning software for freight transport. Therefore, there is scope to apply this low carbon urban logistics tool in further demonstration sites and move the technology to implementation.

BUSUP provides a unique crowd-surfing app, which is in operation in a number of locations in Spain. There is potential for future projects to draw upon the software used in this app to extend the reach of the solution to other cities to encourage the use of buses as an alternative to cars.

Although REMOURBAN offers a broader sustainable urban regeneration model, focusing on areas outside of mobility, it has effectively delivered initiatives to encourage the development of low carbon mobility systems.

6.2.5 Implications for future policy development

The research undertaken in this sub-theme has largely focused on urban areas, with a number of projects moving from the initial research phases to demonstration within the scope of the project. This highlights the growth in models and systems being developed to encourage efficient, low carbon mobility networks in cities.

As new operating models develop, it will be important for policy to ensure that there is a smooth interaction between public transport, urban freight and MaaS. Cities represent hubs of innovation and it will become increasingly important for policy to support the continued development of public transport, to ensure that new modes do not limit its capacity to function.

6.3 Sub-theme 3 – Fair-access public digital infrastructure and mobility data management solutions

This sub-theme covers smart mobility solutions, which adopt a data-centric approach to responding to mobility issues. This sub-theme applies to both passenger and freight transport across all modes. Therefore, key technology themes under this sub-theme include, but are not limited to:

- Tools for mobility data management;
- Logistics and traffic management software;
- Technologies to enhance safety and navigation;
- Fair-access online reservation systems.

This sub-theme is important, as it aims to use data on the current operation of passenger and freight transport to enhance the management of mobility systems and improve the user experience.

6.3.1 Overall direction of R&I

Several areas of research have emerged as key to the development of data management solutions. The application of AI technology to the field of mobility has become increasingly common, as well as the use of big data to enable the development of mobility management systems, which help to improve the passenger user experience and a host of other indicators.

In addition, research is being conducted into using data to empower the user and tailor applications to the needs of individual travellers. Furthermore, a number of projects have used data to improve the safety of the transport network and to enhance navigation. The majority of projects are in the research and validation

development phases. However, results suggest that the TRLs of the selected projects would have progressed following the completion of the project. Projects analysed under this sub-theme are closely linked to the other sub-themes, as many of these projects use data to facilitate improved mobility systems and operating models.

6.3.2 R&I activities

A total of 20 projects were assigned to this sub-theme, with the majority funded by H2020, as highlighted in Table 8. No projects were funded by sources outside of H2020 or FP7.

Table 8. Sub-theme 3 research by parent programme summary.

Parent programme	Total project value	Total EU contribution	Number of projects
H2020	€11,190,495	€4,272,687	17
FP7	€15,507,550	€11,037,965	3
Other	€0	€0	0

Source: TRIMIS.

To provide a more detailed assessment, a number of key projects have been selected to demonstrate the core areas of research undertaken under this sub-theme. The projects have been selected based on one or more of the following criteria: available project results; recent project completion date and high project value.

- UDRIVE (2012-2016) is a project funded by FP7-TRANSPORT, which built upon the PROLOGUE feasibility study, to support the EU to reach environmental and safety targets relating to road transport. The project conducted a Naturalistic Driving (ND) study, built a database for storing ND data and analysed the factors which resulted in crashes and posed potential threats to vulnerable road users, as well as analysing progress in eco-driving technologies. From this analysis, the project then identified measures to improve safety and sustainability, as well as improving driver behaviour models and commercialising ND data applications.
- MOBIS (2012-2015) is a project funded by FP7-ICT, which aimed to develop an intelligent mobility platform through the use of AI and novel technologies. The platform aimed to track and model urban mobility, engaging with stakeholders and drawing on innovative technologies to encourage the development of low carbon mobility systems. MOBIS aims to establish novel AI services, as well as information service platforms, through the collation of data from transport providers, social media and sensors. The solutions were tested through three pilots, in Sweden, Greece and Slovenia.
- TrafficWise (2016-2018) is a project funded by H2020, which aimed to use cellular network data to build the next generation of mobility management platform. The lead partner used AI algorithms to process location data for transport management. The technology anonymously tracks phones to pinpoint locations, developing a sensor network, which provides real-time data on traffic. TrafficWise aimed to upgrade the technology and create a single traffic information platform, which covers real-time traffic, crowd and parking management.
- NOESIS (2017-2019) is a project funded by H2020, which involves the development of a decision support tool for evaluating big data and intelligent mobility systems. The project aims to identify the key features which contribute to the successful implementation of big data technologies in the transport sector. This will be tested through developing a framework to estimate the benefits and costs associated with the application of big data technologies to mobility use cases.
- JAM (2016-2018) is a project funded by H2020, which aimed to develop a solution for increasing the cost-effectiveness of fleet management, through targeting fuel efficiency, maintenance costs and compliance with environmental regulations. JAM gathers data from vehicle sensors, using AI to assess the health of the vehicle, enabling the optimisation of the fleet. The feasibility of JAM was tested during a testing phase with the Small and Medium Enterprise (SME) market. This phase aimed to deliver a version of JAM ready for the market.

6.3.3 Achievements

— The UDRIVE project collected naturalistic driving data for cars, lorries and motorcycles, focusing on the interaction of cyclists and pedestrians, 'eco-driving' practices and the potential safety risks associated with driving. The project results provided a greater understanding of European road user behaviour, collecting over 90,000 hours of data in six European countries. The data has enabled an understanding of the impact of 'eco-friendly' driving practices, such as avoiding necessary braking, which can result in a 25% reduction in fuel consumption in urban areas. The project monitored seatbelt usage, as well as recording that truck drivers spend 20% of their time in vehicles eating, drinking and using mobile phones. The UDRIVE database provides data capable of explaining many other questions relating to driving behaviour, offering the data necessary to extend the research, despite the project itself coming to an end.

— The MOBIS project delivered a range of interesting results to support the development of MaaS. The project involved research into the application of AI techniques, followed by pilot applications for testing the MOBIS concept before disseminating the results in the scientific and business communities. The project concluded with pilot scenarios for an intra-city scenario in Thessaloniki, studying traffic management; an intra-country scenario in Slovenia, considering route planning and an inter-city scenario in Sweden, for commuter journeys. These pilots enabled a greater understanding of the traffic behaviour of citizens, as well testing their user experience of MOBIS.

— TrafficWise developed a number of technologies, which have progressed mobility management. Firstly, the project monitored public and private transport vehicles, separated by mode, and based on cellular data. The project also monitored passengers to enable route planning and broader transportation planning, providing the capacity to answer questions, such as where stations should be located. The monitoring data also enabled the analysis of methods for mitigating congestion.

— Although NOESIS is still underway, the primary outcome is expected to be a decision-support tool, which will help to assess the value associated with investing in machine learning techniques. The project is linking up big data products with transport use cases to determine where big data applications can help to respond to transport challenges. The project is already developing a collection of big data use cases in passenger transport and logistics, to enable an understanding of the potential value associated with big data applications in the transport sector.

— JAM has effectively developed and validated a hardware and software solution, providing vehicle predictive maintenance through AI. The Stratio Plug & Play device targets heavy-duty vehicles, to enable an increase in operational efficiency, as well as a reduction in CO_2 emissions. The device is connected to the vehicle interface for on-board diagnostics, collecting data from vehicle sensors using AI, to signal if a breakdown is likely to occur. The solution has been integrated into the commercial telematics market, enabling predictive maintenance across the transport industry.

6.3.4 Implications for future research

Under this sub-theme, the development phases of the projects analysed are relatively varied. Projects are primarily research or implementation, displaying great variety in technology development across the area of mobility data management and digital infrastructure. This is unsurprising due to the scope of this sub-theme, which covers all transport modes and a variety of data-centric projects.

A number of the selected projects focus on mobility data modelling and management. UDRIVE has developed a naturalistic driving database which sets the foundation for many future studies, offering data on safety, environmental performance and driver activities. In addition, TrafficWise and MOBIS have furthered the mobility management research area.

NOESIS and JAM draw upon machine learning and big data applications. NOESIS is undertaking a broad study, which is aiming to understand the most relevant transport use cases for big data. Therefore, upon completion, this project will offer invaluable insights for future applications of big data in the transport sector. JAM was a more focused project, validating a solution which enables vehicle predictive maintenance. This solution has already been integrated into the telematics market, and therefore, future projects should draw from the key learnings of this project.

6.3.5 Implications for future policy development

As outlined in the policy context, the 2016 review of the Transport White Paper {SWD(2016) 226} highlighted the increased application of big data and ICT tools, in the development of new business models and optimised mobility services. Under H2020 and FP7, a number of data-centric tools have been developed to enhance mobility management. In addition, big data and AI applications are becoming increasingly common. Therefore, it will be important for future policy to support projects, such as NOESIS, which aim to develop appropriate use cases for big data in the transport sector, and respond to the host of safety, environmental and economic issues facing the sector. Where relevant, findings might be transposed into regulations for new vehicles, where these provide clear benefits, e.g. in future amendments to the General Safety Regulation ((EC) No 661/2009).

6.4 Sub-theme 4 – Future intermodality, interoperability and sector-coupling

This sub-theme covers smart mobility solutions which aim to encourage the uptake of multimodal travel. Therefore, key technology themes under this sub-theme include, but are not limited to:

- Tools to encourage multimodality;
- Technologies to enhance rail use and interoperability;
- Future innovative transport solutions.

This sub-theme is important as it aims to enhance intermodality, with a focus on reducing the use of CFVs. Through the development and implementation of large-scale smart tools and technologies, this sub-theme aims to improve the ease of using multiple modes of travel to complete a journey.

6.4.1 Overall direction of R&I

As the need to lower the environmental impact of transport becomes ever more important, encouraging multimodality has become a cornerstone of attempts to reduce the use of CFVs. A number of European funding programmes, such as Shift2Rail, have focused on enhancing interoperability and encouraging passenger and freight transport to move away from the use of road vehicles.

The majority of the selected projects have focused on using software solutions to encourage multimodality, including using data to establish communication networks to facilitate intermodal travel. In addition, projects have encouraged multimodality through enhancing the safety of rail infrastructure, embedding the concept of MaaS and improving interoperability. Therefore, a number of projects have focused on infrastructure, as well as some projects focusing on the development of support systems and tools to encourage multimodal travel.

6.4.2 R&I activities

A total of 13 projects were assigned to this sub-theme, with the majority funded by H2020, as highlighted in Table 9.

Table 9. Sub-theme 4 research by parent programme summary.

Parent programme	Total project value	Total EU contribution	Number of projects
H2020	€38,905,192	€6,747,072	11
FP7	€4,014,702	€2,969,325	1
Other	€0[5]	€0[6]	1

Source: TRIMIS.

To provide a more detailed assessment, a number of key projects have been selected to demonstrate the core areas of research undertaken under this sub-theme. The projects have been selected based on one or more of the following criteria: available project results; recent project completion date and high project value.

- IT2RAIL (2015-2017) is an H2020-funded project, which aimed to develop information technologies under Shift2Rail. The project was aligned with the objectives of Shift2Rail by introducing a technical enabler, which placed the transport user at the centre of the solution, and through providing access to all multimodal services. The project developed a use case on a small scale, which still used scalable architecture. Overall, the project aimed to enhance the ease of intermodal travel, ticketing and planning.
- SAFER-LC (2017-2020) is an H2020-funded project, which aims to improve safety at level crossings, through developing a package of intermodal solutions for the design and management of level crossings. The project aims to provide tools to enable key stakeholders to detect potential collision risks at level crossings and reduce the impact of incidents and disruptions. The project focuses on developing smart detection services and infrastructure to vehicle communication systems, as well as outlining the organisational framework necessary to implement the technical solutions.
- EuTravel (2015-2017) is an H2020-funded project, which enabled individuals to organise a multimodal journey, reflecting their own criteria. The solution enabled travel service providers to deliver customisation, enhancing customer experience through supporting multimodal travel under the customers' terms. The project aimed to develop an open 'Optimodality Framework', which would limit barriers to interoperability and support multimodal travel, from planning to booking. EuTravel also planned to test prototypes in a living lab and test the solutions with stakeholders.
- Shift2MaaS (2018-2020) is a project funded by Shift2Rail, which aims to reduce the barriers to the use of integrated mobility systems. Through improving the ease of integration, the project aims to contribute to the achievement of a Single European Transport Area and Single European Railway Area. The project also aims to lead demonstrations to highlight the value of transport data. The project aims to support the introduction of Shift2Rail IP4 technology in the MaaS arena.

6.4.3 Achievements

- IT2RAIL developed a technical demonstrator to prove that it is possible to increase the attractiveness of rail transport. The project developed a user-centric application, which provides access to multimodal transportation offers, journey tracking and recommended journey alternatives. It also provides insights into journey data and integrates tickets into the app. Therefore, the app provides an innovative one-stop-shop for accessing multimodal journeys, highlighting the advantages of adopting a data-driven approach.
- SAFER-LC is an ongoing project, which is developing technical solutions to enhance safety at level crossings. Although a number of deliverables have been released, such as the exploitation plan, which highlights the actions necessary to ensure the success of SAFER-LC, and to ensure that the outcomes are used in further research, the finalisation of the technologies and recommendations is still under development.

[5] Data on the value of this project (RoCK) is not available via TRIMIS or via the project website. Therefore, the value is listed as € 0.
[6] Data on the EU contribution of this project (RoCK) is not available via TRIMIS or via the project website. Therefore, the value is listed as €0.

— EuTravel has delivered several key solutions for enabling 'optimodal travel'. The project has supported the development of tools which make use of existing reservation systems and data solutions. EuTravel developed a data integration infrastructure for multimodal travel to be used primarily by travel service providers. In addition, a prototype multimodal planner for aviation, waterborne, rail and road transport was developed. This planner enables individuals to tailor journeys to their needs, from a smartphone, PC or tablet.

— The Shift2MaaS project is an ongoing project, which combines the broader attempts to encourage multimodality with the development of MaaS. The project kick-off took place in January 2019 outlining plans to test the solution at three sites which are engaged in intermodality and MaaS. The project will work to identify the technology needs required by key stakeholders to ensure that passenger experience is prioritised, validating use cases for the implementation of solutions.

6.4.4 Implications for future research

This sub-theme has seen relatively fewer projects funded by H2020 and FP7, of which the majority involve the early stages of technology development (research). Therefore, many of the projects have set the foundation for further development, providing essential insights into the development of interoperable networks.

IT2RAIL and EuTravel offer similar solutions, enhancing the ease of multimodality for passengers. Fewer H2020-funded and recent FP7 projects have focused on enhancing interoperability and intermodality in the freight sector, suggesting that there is capacity for research in this area. However, it is important to note that freight interoperability is funded by other funding programmes and bodies, such as the EU Agency for Railways. Although Shift2MaaS is still ongoing, it offers a unique combination of the Shift2Rail and MaaS concepts, aiming to enhance intermodality and mobility as a service. Therefore, the results of this project will provide an understanding of progress in both of these areas, as well as the potential to combine these concepts to drive the shift away from private vehicle use towards intermodal travel.

SAFER-LC builds on a foundation of projects aiming to enhance rail safety through the combined use of infrastructural improvements and technological solutions. Once the project is finalised, it will provide useful insights into the collective use of infrastructure and technology to support safety, which future projects could develop further.

6.4.5 Implications for future policy development

As discussed in the policy context, the ITS Directive outlines several policy measures to support EU-wide multimodal travel information for ITS users. Where relevant, the conclusions of projects such as IT2RAIL and EuTravel could be further facilitated by this Directive. As user data becomes increasingly central to supporting the uptake of intermodal travel, it will be important to ensure that policy supports the privacy of the data of individuals.

6.5 Sub-theme 5 – Validation and integration of automated, air and virtual mobility

This sub-theme covers smart mobility solutions which aim to enhance the management and operation of automated, air and virtual mobility systems. Therefore, key technology themes under this sub-theme include, but are not limited to:

- Smart airports and air traffic management;
- Communication networks for intelligent vehicles;
- Drone traffic management;
- Drone communication networks and surveillance;
- Teleworking and teleconferencing technologies.

This sub-theme is important as it addresses the latest technologies and systems used to improve the operation of drone systems, as well as covering the development of communication networks for automated vehicles. Therefore, this sub-theme is important in highlighting current areas of research in this newly-developing area, as well as displaying where significant gaps lay.

6.5.1 Overall direction of R&I

Drones and associated drone technologies are still relatively new to market. Therefore, at this stage, a significant amount of funding is coming from the private sector, with only 12 projects identified that were funded by European funding programmes between 2015 and 2022. However, programmes which are focused on ATM and enhancing the operational efficiency of airports, and aviation more broadly, are funded more substantially by European programmes.

The majority of projects focusing on automated mobility in the SMO roadmap involve the use of data and software to enhance connectivity between vehicles, through communication networks. Currently, there are few projects focused on virtual mobility. However, it is expected that projects addressing this field will grow in the coming years.

6.5.2 R&I activities

A total of 23 projects are assigned to this sub-theme, all which were funded by H2020, as highlighted in Table 10.

Table 10. Sub-theme 5 research by parent programme summary.

Parent programme	Total project value	Total EU contribution	Number of projects
H2020	€41,844,233	€10,149,220	23
FP7	€0	€0	0
Other	€0	€0	0

Source: TRIMIS.

To provide a more detailed assessment, a number of key projects have been selected to demonstrate the core areas of research undertaken under this sub-theme. The projects have been selected based on one or more of the following criteria: available project results; recent project completion date and high project value. From the analysis, the vast majority of projects focused on drone technologies and aviation and therefore, these are the projects selected below.

- AIRMES (2015-2019) is an H2020-funded project concerned with airline maintenance operations. The project aimed to develop and validate integrated maintenance service architecture, which aimed to reduce the occurrence of operational disruptions in air traffic. The service architecture would support the transformation in aviation, from scheduled to condition-based maintenance. The service architecture will also make use of augmented reality technologies and communication systems to provide an information system which is fully integrated.
- PASSME (2015-2018) is an H2020-funded project, which aimed to deliver passenger-centric solutions to prepare for the expected increase in the demand for commercial flights in Europe. The primary aim was to integrate information systems in order to reduce travel time, implementing innovative solutions, such as systems for managing passenger flows, luggage management, boarding management and smartphone applications for measuring mental wellbeing of passengers at airports to improve the passenger experience.
- DroC2om (2017-2019) is an H2020-funded project based on drone critical communications. The key aim of the project is to develop the architecture for a cellular-satellite system, which offers the safe use of remote-controlled unmanned aerial systems. This will be based on the modelling of real drone systems. The project partners are diverse in nature to ensure that the project delivers solutions that are relevant to multiple technological areas, including telematics, aerospace communications and mobile networks.
- PODIUM (2018-2019) is an H2020-funded project, which involved large-scale demonstrations of drone operations and traffic management in France, Denmark and the Netherlands. The demonstrations enabled a range of different users to test the functionality of the drone traffic management system, including government authorities and drone pilots. The demonstrations enabled a comprehensive appreciation of the potential and TRL of PODIUM functionalities.
- SafeClouds (2016-2019) is an H2020-funded project, which proposed a data-driven approach to aviation safety assurance. The project developed a safety data analysis approach, which aims to extract safety intelligence in a connected, efficient manner, through fostering collaboration between aviation and technology stakeholders. SafeClouds aimed to develop novel data structures and a proof of concept validated in a lab. The project brought together key stakeholders from across the sector and data cycle to enable progression in aviation safety analytics in Europe.
- CORUS (2017-2019) is an H2020-funded project, which is developed an operational concept for enabling the safe interaction between all airspace users. It aims to address the lack of harmonisation in regard to integrating unmanned aerial vehicles (UAVs) in low level airspace. The project aims to develop a concept for unmanned aircraft system traffic management (UTM), developing use cases for key scenarios and accounting for the societal impacts of drones. A community network will be established to engage a variety of stakeholders in the development of the UTM, to ensure the concept is widely accepted.
- CREATE (2015-2018) is an H2020-funded project, which aimed to tackle urban road congestion. The project aimed to develop practical definitions of urban road congestion and network performance, and

identify factors influencing conditions in different cities. Through analysing congestion and network performance data in Western European cities, the project aimed to understand better how cities have succeeded in decoupling traffic growth from economic growth. Following this, CREATE planned to develop concrete guidance and provide capacity building for cities in Central and Eastern Europe. The project also aimed to engage with leading technology providers and private organisations, to explore the requirements for providing high-quality mobility in cities facing population and employment growth.

6.5.3 Achievements

- In March 2019, AIRMES performed its final demonstrations at the TAP Air Portugal Hub in Lisbon. This demonstration proved that maintenance can be fully digitalised, as well as highlighting the capacity to use innovative solutions to enhance decision-making and provide access to information. Therefore, the project has identified potential solutions for enhancing the efficiency of maintenance operations, reducing delays and therefore, improving the passenger experience.
- The PASSME project delivered a number of key achievements, which have contributed to savings of 60 minutes of travel time per trip to the airport. The combined development of passenger demand forecast systems, separated luggage travel, passenger-centric airport and airplane interiors and personalised smartphone applications have contributed to these time savings. PASSME has enabled an understanding of the distinction between wanted and unwanted waiting time at airports. The project has demonstrated the technical feasibility of the various systems and applications, as well as gaining positive stakeholder feedback for further utilisation of PASSME breakthroughs.
- Although DroC2om is ongoing, a number of deliverables have been produced. The project has researched cellular system concepts for terrestrial communications and UAS communications, providing recommendations for network upgrades. The project has also analysed existing satellite systems, concluding that there is a need to develop dedicated satellite communication concepts for drones. As the project continues, insights from simulation experiments on combined cellular-satellite UAS communication will be shared, alongside reports on the standardisation and dissemination of research.
- SafeClouds is an ongoing project, which has demonstrated the capacity of data science and intelligent systems to enhance safety levels cost-effectively. The project is applying AI to safety hazards prediction and analysis, developing and testing algorithms used in particular safety scenarios (i.e. terrain warnings, runway safety). The project has also developed DataBeacon, a scalable on-demand computing platform, which provides the data infrastructure for AI aviation applications. In addition, Smart Data Fusion was developed, which enables the confidential merging of data. This has permitted the development of a comprehensive view of safety scenarios, through collating data from several stakeholders and maintaining anonymity.
- CORUS is an ongoing project, which is working towards establishing a common operational concept for UAVs operating in low lying airspace. To date, CORUS has brought together stakeholders to design, refine and validate a concept of operation. The project has explored high-level service architecture, safety-related issues, societal impacts (i.e. privacy, liability) and the research activities necessary to drive the concept forward.
- CREATE developed a more critical understanding of the strengths and weaknesses of different methods of measuring congestion and network performance, as well as providing an understanding of how these methods can influence policymaking. The project also provided policymakers with insights into the roles that demographic and economic shifts play in driving travel trends. In addition, the analysis provided policymakers with insights into the roles of legislation and funding in delivering policies which focus on liveability, through improving the built environment and discouraging car use. The results of CREATE are currently being built upon by an ongoing project, MORE, which aims to develop procedures for dynamic road space reallocation in urban areas. This project aims to facilitate the co-design of urban corridor infrastructure which feeds in to the TEN-T network, addressing key concerns in urban areas, including congestion, safety and air pollution.

6.5.4 Implications for future research

To date, the majority of the large-scale projects have involved the research of innovative technologies, particularly in relation to drone traffic management and communication systems. Therefore, many of the projects have set the foundation for further development, with private sector research into drone technologies complementing the projects funded by H2020. Over the past few years, H2020-funded projects

focusing on drones have been operating in an uncertain regulatory landscape. Therefore, projects such as CORUS have offered essential insights into the views of key stakeholders in the industry, driving the movement towards a cohesive operational concept for the operation and traffic management of drones, which considers safety and societal impacts more broadly.

Similarly, projects such as DroC2om are providing a greater understanding of drone communication systems, engaging with a broad range of stakeholders in industry and academia to ensure the safe use of remote-controlled drones. In the selected projects, there is a clear focus on using technology to enhance the safety of drone operations. Therefore, future projects should build on the findings of these projects, drawing on existing stakeholder engagement outputs and technology development, to bring solutions to market.

The projects focusing on aviation vary more broadly in nature, from air traffic management systems and airport maintenance to AI safety applications. The majority of projects are still at the research stage. However, PASSME is at the demonstration/prototyping/pilot production phase (TRL 6). Both PASSME and AIRMES focused on improving the efficiency of operations, primarily to enhance the passenger experience. As both of these projects are still ongoing, there is scope for future projects to build on the research and demonstrations undertaken through these projects to implement tested solutions.

6.5.5 Implications for future policy development

As outlined in the policy context, {COM(2014) 207} sets a European strategy for the development of a common market of drone services and aircraft. The Implementing Act, regulating the operation of UAS, will reduce the fragmented nature of current safety rules regarding drones. This will provide greater clarity for future research. Current projects focusing on drones, such as DroC2om and CORUS, have undertaken widespread stakeholder engagement to broaden the understanding of the safety implications of drone operations. Therefore, there is scope for future policy to draw on the findings of these projects, to ensure that a clear framework for drone operations is in place.

Future policy will also need to account for the growing use of AI to enhance the efficiency, safety and environmental performance of aviation. However, unlike drones, legislation regarding aviation has been developing over a number of decades, and there are no clear gaps in current policy which have been identified by the selected projects.

7 Conclusions

Focusing on selected EU funded projects, this report presents a comprehensive analysis of R&I on smart mobility and services in Europe in the last years. The report identifies relevant researched technologies and their development phase and highlights the relevant policy context and the market activities both in Europe and outside. From the assessment carried out, the key conclusions are:

- Under FP7 and H2020 about €1 bn has been invested in SMO research projects. This includes €870 m of EU funds and about €130 m of own contributions by beneficiary organisations.
- A total of 1,621 unique organisations participated in FP7 and/or H2020 projects on SMO. The vast majority of the organisations involved focus on more than one transport modes, and all of them include multimodality in their activities. Multimodal applications are the most popular followed by road. Rail, air and water have much less instances compared to the two main ones.
- In many projects a large number of organisations from various countries participate. Italy is the largest beneficiary in absolute terms, followed by Germany. Even though an imbalance exists between the various countries in terms of SMO research, it does appear to be less profound when compared to the other STRIA roadmaps.
- Spending on SMO research under H2020 peaked in the first quarter of 2018. Multimodal transport received the greatest interest, while waterborne transport receives the smallest amount of funds for SMO research amongst all modes.
- From a text analysis on scientific research from the Scopus database, the number of publications in SMO in general has an increasing trend from year to year, with documents related to the term "smart mobility" rising from only 1 in 2010 to 150 and 127 in 2018 and 2019 respectively. Interestingly, the term "smart mobility" is mostly used in Europe (7 out of 10 countries are in the EU, with Italy being the dominant one). "Mobility as a service" is an area of research related to urban mobility and that has been trending in the last five years peaking in 2018 and 2019, with the US appearing by far the first in terms of publications, followed by Germany and the UK from Europe. The US, China and large EU countries generally occupy the first places in terms of SME-related scientific publications. A notable case that should be highlighted is the domain of urban air (drone) mobility where the EU presence is minimal and the US are clearly leading. On the upside European countries are leading when in the domains of soft or active mobility and the concept of living labs. Both urban air (drone) mobility and living labs are trending areas with a low number of outputs that offer opportunity for research.
- The technology analysis highlights clusters that are researched in FPs at different development phases. The concept of development phase as an indication of technology maturity has been consolidated in the TRIMIS assessment methodology and is widely used in this report. Three of the top-10 technologies have been researched over the entire development phase in FPs. E-ticketing scheme has been researched only at a research phase, something indicative of the (still) low maturity of these technologies. This is also the case for mobility services open platform concept researched at research and validation phase. COMM network for intelligent mobility, evidence-based road safety research, Eco-Drive app, MaaS model, and, car-sharing platform have been researched significantly also in implementation projects.
- Among the top-20 technologies, 12 are linked to road transport, 6 to multimodal transport, 1 to aviation (personal aerial transportation systems), 1 to rail (track side train presence alert) and 1 to waterborne transport (E-freight systems). Communication network for intelligent mobility has received the highest funding: almost half of it (€45 m) through two large scale H2020 projects.

More specific findings focus on the R&I of the 5 sub-themes.

On the sustainable and integrated smart mobility systems sub-theme:

- To date, the majority of large-scale SMO projects have involved research of innovative technologies. Therefore, many of the projects have set the foundation for further development, with validation, demonstration and implementation at a larger scale still necessary. Under this sub-theme, the development of technologies for VRUs, software to support active travel uptake and sustainable mobility, and tools to enhance intelligent freight systems are all still relevant areas of research. Therefore, building upon projects that have since finished will enable projects to develop beyond the initial research development phases, to reach demonstration and implementation.

— As many projects are developing solutions to similar issues, there is greater scope to enhance cohesion and knowledge-sharing between projects. In the area of active travel, this is particularly applicable, with many projects aiming to enhance the uptake of cycling in cities.

— Focused research has provided a pivotal development in carpooling technologies, demonstrating the use case for carpooling in several cities in Europe while it provides a host of developments across sustainable transport, from carpooling to a demand-responsive bus service offering invaluable evidence for cities around Europe in the process of developing their SUMPs.

— The projects completed under this sub-theme offer significant innovations in the context of safer, low carbon mobility systems. As outlined in the policy context, European policy on shared and on-demand mobility services has yet to be fully developed. Therefore, as innovations continue to occur in this area, further policy development may be necessary. However, there is not a complete gap in the policy area, with the Low Emissions Mobility Strategy highlighting the importance of shared mobility schemes, such as car-pooling services, in relation to sustainable urban mobility. Where ITS technologies are proven to be beneficial, their implementation under the ITS Directive (2010/40/EU) could be facilitated.

On the design of effective operating models sub-theme:

— The majority of projects are at the early research stage, with several also at the demonstration and implementation phases.

— Some of the key areas researched under this broad sub-theme include the growing field of account-based traveling and services to encourage the uptake of low carbon transport. Various solutions, applications and models, have been tested in a number of cities, paving the way for future research into ITS solutions for passengers and to encourage the use of buses as an alternative to cars and to encourage the development of low carbon mobility systems.

— The research undertaken in this sub-theme has largely focused on urban areas, with a number of projects moving from the initial research phases to demonstration within the scope of the project. This highlights the growth in models and systems being developed to encourage efficient, low carbon mobility networks in cities.

— As new operating models develop, it will be important for policy to ensure that there is a smooth interaction between public transport, urban freight and MaaS. Cities represent hubs of innovation and it will become increasingly important for policy to support the continued development of public transport, to ensure that new modes do not limit its capacity to function.

On the fair-access public digital infrastructure and mobility data management solutions sub-theme:

— The development phases of the projects analysed under this sub-theme are relatively varied. Projects are primarily research or implementation, displaying great variety in technology development across the area of mobility data management and digital infrastructure. This is unsurprising due to the scope of this sub-theme, which covers all transport modes and a variety of data-centric projects.

— A number of the selected projects focus on mobility data modelling and management, including the notion of naturalistic driving databases, machine learning and big data that will offer invaluable insights for future applications of big data in the transport sector. More focused applications have also been developed as in the case solutions enabling vehicle predictive maintenance, which has already been integrated into the telematics market.

— The 2016 review of the Transport White Paper {SWD(2016) 226} highlighted the increased application of big data and ICT tools, in the development of new business models and optimised mobility services. Under H2020 and FP7, a number of data-centric tools have been developed to enhance mobility management. In addition, big data and AI applications are becoming increasingly common. Therefore, it will be important for future policy to support projects aiming to develop appropriate use cases for big data in the transport sector, and respond to the host of safety, environmental and economic issues facing the sector. Where relevant, findings might be transposed into regulations for new vehicles, where these provide clear benefits, e.g. in future amendments to the General Safety Regulation ((EC) No 661/2009).

On the implementation of intermodality, interoperability and sector coupling sub-theme:

— This sub-theme has seen relatively fewer projects funded by H2020 and FP7, of which the majority involve the early stages of technology development (research). Therefore, many of the projects have set

the foundation for further development, providing essential insights into the development of interoperable networks.

— Some key projects offer similar solutions, enhancing the ease of multimodality for passengers. Fewer H2020-funded and recent FP7 projects have focused on enhancing interoperability and intermodality in the freight sector, suggesting that there is capacity for research in this area. However, it is important to note that freight interoperability is funded by other funding programmes and bodies, such as the EU Agency for Railways. Another aim is to enhance intermodality and mobility as a service and thus the results of the relevant research will provide an understanding of progress in both of these areas, as well as the potential to combine these concepts to drive the shift away from private vehicle use towards intermodal travel. Another element is safety with research also aiming to provide useful insights into the collective use of infrastructure and technology to support safety.

— The ITS Directive outlines several policy measures to support EU-wide multimodal travel information for ITS users. The conclusions of relevant projects in this area could be further facilitated by this Directive. As user data becomes increasingly central to supporting the uptake of intermodal travel, it will be important to ensure that policy supports the privacy of the data of individuals.

On the validation and integration of automated, air and virtual mobility sub-theme:

— The majority of the large-scale projects have involved the research of innovative technologies, particularly in relation to drone traffic management and communication systems. Therefore, many of the projects have set the foundation for further development, with private sector research into drone technologies complementing the projects funded by H2020. Over the past few years, H2020-funded projects focusing on drones have been operating in an uncertain regulatory landscape. Therefore, relevant projects have offered essential insights into the views of key stakeholders in the industry, driving the movement towards a cohesive operational concept for the operation and traffic management of drones, which considers safety and societal impacts more broadly.

— Other projects are providing a greater understanding of drone communication systems, engaging with a broad range of stakeholders in industry and academia to ensure the safe use of remote-controlled drones. In the selected projects, there is a clear focus on using technology to enhance the safety of drone operations. Therefore, future projects should build on the findings of these projects, drawing on existing stakeholder engagement outputs and technology development, to bring solutions to market.

— The projects focusing on aviation vary more broadly in nature, from air traffic management systems and airport maintenance to AI safety applications. The majority of projects are still at the research stage with exceptions at the demonstration/prototyping/pilot production phase (TRL 6) focused on improving the efficiency of operations, primarily to enhance the passenger experience.

— On the policy side, {COM(2014) 207} sets a European strategy for the development of a common market of drone services and aircraft. The Implementing Act, regulating the operation of UAS, will reduce the fragmented nature of current safety rules regarding drones. This will provide greater clarity for future research. A series of current projects focusing on drones have undertaken widespread stakeholder engagement to broaden the understanding of the safety implications of drone operations. Therefore, there is scope for future policy to ensure that a clear framework for drone operations is in place.

— Future policy will also need to account for the growing use of AI to enhance the efficiency, safety and environmental performance of aviation. However, unlike drones, legislation regarding aviation has been developing over a number of decades, and there are no clear gaps in current policy which have been identified by the selected projects.

Altogether, this report provides a comprehensive and up-to-date review of SMO R&I across Europe. Although with limitations (more notably, the lack of MS projects in the assessment), findings and insights into the current R&I status and future needs, help the STRIA WG to better identify R&I activities and provide valuable information to smart mobility and services stakeholders.

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List of abbreviations and definitions

ACEA	European Automobile Manufacturers' Association
AI	Artificial Intelligence
ALT	Low-Emission Alternative Energy for Transport
AT	Austria
ATM	Air Traffic Management
BE	Belgium
BG	Bulgaria
C-ITS	Cooperative Intelligent Transport Systems
CAM	Connected and Automated Mobility
CAT	Connected and Automated Transport
CEF	Connecting Europe Facility
CFV	Conventionally-Fuelled Vehicle
CO_2	Carbon Dioxide
COMM	Communication
CORDIS	Community Research and Development Information Service
CPC	Cooperative Patent Classification
CY	Cyprus
CZ	Czechia
DE	Germany
DG MOVE	Directorate-General for Mobility and Transport
DG RTD	Directorate-General for Research and Innovation
DK	Denmark
DSM	Digital Single Market
DTR	Demand Responsive Transport
EC	European Commission
EE	Estonia
eMaaS	Electromobility-as-a-Service
EL	Greece
ELT	Transport Electrification
ERSO	European Road Safety Observatory
ES	Spain
ETC	European Travellers Club
EU	European Union
EU-13	Group of 13 EU countries: Bulgaria (BG), Croatia (HR), Cyprus (CY), Czechia (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Lithuania (LT), Malta (MT), Poland (PL), Romania (RO), Slovakia (SK) and Slovenia (SI)
FI	Finland
FP	Framework Programme
FP7	7th Framework Programme for Research

FR	France
GHG	Greenhouse Gas
GNSS	Global Navigation Satellite System
H2020	Horizon 2020 Framework Programme for Research and Innovation
HGV	Heavy Goods Vehicle
HMI	Human Machine Interface
HR	Croatia
HU	Hungary
ICAO	International Civil Aviation Organisation
ICT	Information and Communication Technologies
IE	Ireland
INF	Transport Infrastructure
IoT	Internet of Things
IT	Italy
ITS	Intelligent Transport Systems
JRC	Joint Research Centre
LT	Lithuania
LU	Luxembourg
LV	Latvia
MaaS	Mobility-as-a-Service
MFF	Multiannual Financial Framework
MIT	Massachusetts Institute of Technology
MS	Member State
MT	Malta
ND	Naturalistic Driving
NASA	National Aeronautics and Space Administration
NETT	New and Emerging Technologies and Trends
NL	Netherlands
NTM	Network and Traffic Management
PL	Poland
PT	Portugal
R&D	Research and Development
R&I	Research and innovation
REGEX	Regular Expressions
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
SME	Small and Medium Enterprise

SMMT	Society of Motor Manufacturers and Traders
SMO	Smart Mobility and Services
STRIA	Strategic Transport Research and Innovation Agenda
SUMP	Sustainable Urban Mobility Plan
TRIMIS	Transport Research and Innovation Monitoring and Information System
TRL	Technology Readiness Level
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicles
UK	United Kingdom
US	United States
UTM	Unmanned Aircraft System Traffic Management
VDM	Vehicle Design and Manufacturing
VRU	Vulnerable Road User
WG	Working Group

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Annexes

Annex 1. Project tables

The following table shows all projects that were considered during the development of this report and the sub-theme(s) under which they were considered.

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
2MOVE2	New forms of sustainable urban transport and mobility	2012-2016	FP7-TRANSPORT	Y				
3IBS	The Intelligent, Innovative, Integrated Bus Systems	2012-2015	FP7-TRANSPORT		Y			
ADS Project	Autonomous Dronistics for Security (ADS): optimized services with fleets of flying robots	2015-2015	H2020-EU.2.1.					Y
AIRMES	Airline Maintenance Operations implementation of an E2E Maintenance Service Architecture and its enablers	2015-2019	H2020-EU.3.4.					Y
Airport IQ	Situation-Aware Mobile Platform for Airport Collaborative Decision-Making	2015-2017	H2020-EU.3.4.					Y
ATTRACkTIVE	Advanced Travel Companion and Tracking Services	2018-2018	H2020-EU.3.4.		Y			
Avionero	Avionero - a new standard in flight search	2017-2018	H2020-EU.3.4.					Y
BigData4ATM	Passenger-centric Big Data Sources for Socio-economic and Behavioural Research in ATM	2016-2018	H2020-EU.3.4.			Y		Y
BITRIDE BIKE SHARING	The solution for flexible bike sharing initiatives without fixed stations	2017-2018	H2020-EU.3.4.	Y				

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
BONVOYAGE	From Bilbao to Oslo, intermodal mobility solutions and interfaces for people and goods, supported by an innovative communication network	2015-2018	H2020-EU.3.4.				Y	
BUSUP	BusUp: Multi-platform On-demand Crowdsourced Bus Transportation for Smart City Mobility	2017-2018	H2020-EU.3.4.		Y			
CANGOPAL	Next generation of Carrier Open SaaS for boosting e-Commerce economy	2016-2017	H2020-EU.3.4.	Y				
Cargo Beacon	Cargo Beacons - no unexpected delays or losses in shipments of valuable cargo	2016-2017	H2020-EU.3.4.			Y		
CIMEC	Cooperative ITS for Mobility in European Cities	2015-2017	H2020-EU.3.4.		Y			
CIPTEC	Collective Innovation for Public Transport in European Cities	2015-2018	H2020-EU.3.4.	Y				
City.Risks	Avoiding and mitigating safety risks in urban environments	2015-2018	H2020-EU.3.7.			Y		
CITY-HUB	City-Hub	2012-2015	FP7-TRANSPORT		Y			
CIVITAS CAPITAL	CIVITAS CAPITAL - making the best of CIVITAS!	2013-2016	FP7-TRANSPORT	Y				
CO-ACTIVE	CO-modal journey re-ACcommodation on associated Travel serVices	2016-2018	H2020-EU.3.4.				Y	

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
COLDTRACK	New cloud-base SW for ensuring the Cold Chain during Food Transportation	2017-2017	H2020-EU.3.4.	Y				
CORUS	Concept of Operations for EuROpean UTM Systems	2017-2019	H2020-EU.3.4.					Y
CREATE	Congestion Reduction in Europe : Advancing Transport Efficiency	2015-2018	H2020-EU.3.4.					Y
DAPS	Drone Alarm and Protection System	2016-2016	H2020-EU.3.7.					Y
DREAMS	DRone European AIM Study	2017-2019	H2020-EU.3.4.					Y
DroC2om	Drone Critical Communications	2017-2019	H2020-EU.3.4.					Y
E-APIS	A smart, energy autonomous, universal and cost-effective dynamic passenger information system	2017-2017	H2020-EU.3.4.		Y			
EBSF_2	European Bus Systems of the Future 2	2015-2018	H2020-EU.3.4.		Y			
EMERALD	Energy ManagEment and RechArging for efficient eLectric car Driving	2012-2015	FP7-ICT		Y			
EMPOWER	EMPOWERING a reduction in use of conventionally fuelled vehicles using Positive Policy Measures.	2015-2018	H2020-EU.3.4.	Y				

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
ENABLE-S3	European Initiative to Enable Validation for Highly Automated Safe and Secure Systems	2016-2019	H2020-EU.2.1.			Y		
ESPRIT	Easily diStributed Personal RapId Transit	2015-2018	H2020-EU.3.4.		Y			
ETC	The European Travellers Club: Account-Based Travelling across the European Union	2015-2017	H2020-EU.3.4.		Y			
EuTravel	Optimodal European Travel Ecosystem	2015-2017	H2020-EU.3.4.				Y	
EVA	Smart city navigation tool for the visually impaired	2017-2017	H2020-EU.3.4.	Y		Y		
EVOLUTION	The Electric Vehicle revOLUTION enabled by advanced materials highly hybridized into lightweight components for easy integration and dismantling providing a reduced life cycle cost logic	2012-2016	FP7-NMP		Y			
EXTREMDRON	Unmanned aerial vehicle for vigilance, control and critical urban infrastructure protection	2016-2016	H2020-EU.3.7.					Y
FASTPRK-2	Enhanced on-street parking management system (2)	2016-2018	H2020-EU.3.4.	Y				
FLOW	Furthering Less Congestion by creating Opportunities for more Walking and cycling	2015-2018	H2020-EU.3.4.	Y				
GlobILS	Global Platform for Indoor Location Services	2016-2018	H2020-EU.3.4.				Y	

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
GoF4R	Governance of the Interoperability Framework for Rail and Intermodal Mobility	2016-2018	H2020-EU.3.4.				Y	
GoOpti	GoOpti - Profitable, Smart and Professional DRT over Long Distances	2016-2018	H2020-EU.3.4.		Y			
HomyHub	Unlocking the full potential of garages and paving the way for 21st century garage	2017-2018	H2020-EU.3.4.	Y				
IMOVE	Unlocking Large-Scale Access to Combined Mobility through a European MaaS Network	2017-2019	H2020-EU.3.4.					Y
IMPACT	Impact of Cultural aspects in the management of emergencies in public Transport	2015-2017	H2020-EU.3.7.		Y			
IMPETUS	Information Management Portal to Enable the inTegration of Unmanned Systems	2017-2019	H2020-EU.3.4.					Y
INAS	Integra A/S - Service provider of drones for civil use	2015-2015	H2020-EU.3.4.					Y
InDeV	InDeV: In-Depth understanding of accident causation for Vulnerable road users	2015-2018	H2020-EU.3.4.	Y				
iShare	iShare - a disruptive approach to vehicle sharing	2017-2017	H2020-EU.3.4.	Y				
IT2RAIL	Information Technologies for Shift to Rail	2015-2017	H2020-EU.3.4.				Y	

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
ITS OBSERVATORY	ITS Observatory	2015-2017	H2020-EU.3.4.			Y		Y
JAM	JAM: vehicle predictive maintenance through Artificial Intelligence	2016-2018	H2020-EU.3.4.			Y		
KAROS	KAROS - Integration of a dynamic and predictive short distance carpooling offer into route planner services	2017-2017	H2020-EU.3.4.			Y		
LOCARP4EU	potential analysis of Ecov's short-distance real-time carpooling stations relying on roadside connected hardware	2017-2017	H2020-EU.3.4.	Y				
LOOP	Disrupting Logistics in Smart Cities and Regions through an Advanced Logistics Platform.	2016-2017	H2020-EU.3.4.	Y				
MASAI	Mobility Based on Aggregation of Services and Applications Integration	2015-2018	H2020-EU.3.4.		Y			
MFDS	Multi-Functional Detective System (MFDS) - Advanced, 'Intelligent Transport System' creating smarter and safer European roads	2017-2017	H2020-EU.3.4.			Y		
MFDS	Multi-Functional Detective System (MFDS) -Advanced, 'Intelligent Transport System' creating smarter and safer European roads	2017-2017	H2020-EU.3.4.		Y			
MIND-SETS	Mobility Innovations for a New Dawn in Sustainable (European) Transport Systems	2014-2017	H2020-EU.3.4.			Y		

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
MOBILITY2.0	Co-operative ITS Systems for Enhanced Electric Vehicle Mobility	2012-2015	FP7-ICT		Y			
MOBILITY4EU	Action Plan for the future of Mobility in Europe	2016-2018	H2020-EU.3.4.				Y	
MOBINCITY	SMART MOBILITY IN SMART CITY	2012-2015	FP7-ICT		Y			
MOBIS	Personalized mobility services for energy efficiency and security through advanced artificial intelligence techniques	2012-2015	FP7-ICT			Y		
MoNIfly	Mobile-Network Infrastructure for Cooperative Surveillance of low flying drones	2017-2020	H2020-EU.3.4.					Y
MSH	The one-stop-shop for urban and regional mobility	2017-2018	H2020-EU.3.4.		Y			
My-TRAC	My TRAvel Companion	2017-2020	H2020-EU.3.4.		Y			
NB4WASTE	Narrowband IoT for Waste Collection in Rural Areas	2017-2017	H2020-EU.3.4.		Y			
NODES	New tOols for Design and OpEration of Urban Transport InterchangeS	2012-2015	FP7-TRANSPORT	Y				
NOESIS	NOvel Decision Support tool for Evaluating Strategic Big Data investments in Transport and Intelligent Mobility Services	2017-2019	H2020-EU.3.4.			Y		

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
NOVELOG	New cooperative business models and guidance for sustainable city logistics	2015-2018	H2020-EU.3.4.		Y			
OMNISCIENT	Prediction and optimisation platform for the mobile assets management	2018-2018	H2020-EU.3.4.	Y				
OnTrack	Development of a commercial manufacturing process for embeddable RFID and NFC Tags for complete lifecycle tracking of tyres	2017-2019	H2020-EU.3.4.			Y		
OPTELA	Disrupting the telematics market with an ultra-low cost and high performance self-learning open platform	2017-2018	H2020-EU.3.4.					Y
OPTICITIES	Optimise Citizen Mobility and Freight Management in Urban Environments	2013-2016	FP7-TRANSPORT		Y			
OPTIMUM	Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility	2015-2018	H2020-EU.3.4.				Y	
OUITAXI	OUITAXI (or WETAXI) a taxi on demand and taxi sharing service	2017-2017	H2020-EU.3.4.	Y				
P2PCS	Peer-2-peer Car Sharing	2017-2017	H2020-EU.3.4.	Y				
PAL	Public Space Navigation for All	2016-2017	H2020-EU.3.4.			Y		
PASSME	Personalised Airport Systems for Seamless Mobility and Experience	2015-2018	H2020-EU.3.4.					Y

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
Pavnext	NextGen Road Safety for smarter cities	2018-2018	H2020-EU.3.4.			Y		
PercEvite	PercEvite - Sense and avoid technology for small drones	2017-2020	H2020-EU.3.4.					Y
PODIUM	Proving Operations of Drones with Initial UTM Management	2018-2019	H2020-EU.3.4.					Y
PRIVACY FLAG	Enabling Crowd-sourcing based privacy protection for smartphone applications, websites and Internet of Things deployments	2015-2018	H2020-EU.3.7.			Y		
Prosperity	Prosperity through innovation and promotion of Sustainable Urban Mobility Plans	2016-2019	H2020-EU.3.4.	Y				
PROXITRAK	PROXITRAK - next generation IoT tracking solution for a connected logistics - collect, analyse and visualise big data in a true real time	2017-2017	H2020-EU.3.4.	Y				
REMOURBAN	REgeneration MOdel for accelerating the smart URBAN transformation	2015-2019	H2020-EU.3.3.		Y			
RoCK	Regions of Connected Knowledge	2007-2015	INTERREG IVB				Y	
SafeClouds.eu	Data-driven research addressing aviation safety intelligence	2016-2019	H2020-EU.3.4.					Y
SAFER-LC	SAFER Level Crossing by integrating and optimizing road-rail infrastructure management and design	2017-2020	H2020-EU.3.4.				Y	

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
SECOPS	An Integrated Security Concept for Drone Operations	2017-2019	H2020-EU.3.4.					Y
SENIORS	Safety-ENhancing Innovations for Older Road userS	2015-2018	H2020-EU.3.4.	Y				
SETA	An open, sustainable, ubiquitous data and service ecosystem for efficient, effective, safe, resilient mobility in metropolitan areas	2016-2019	H2020-EU.2.1.	Y				
Shift2MaaS	Shift2Rail IP4 enabling Mobility as a Service and seamless passenger experience	2018-2020	Shift2Rail				Y	
SHOKA	Community-based cyclist navigation solution to increase safety of utility bikers	2017-2017	H2020-EU.3.4.	Y				
SHOTL	A shared mobility On-Demand Service	2016-2017	H2020-EU.3.4.		Y			
SIADE SaaS	SIADE SaaS: Spatial Decision Support System for Transportation Planning	2017-2019	H2020-EU.3.4.		Y			
SMART BIKING 2	Safe parking system for bicycles (2)	2017-2019	H2020-EU.3.4.	Y				
SMART E67	Advanced traffic management on E67 transport corridor	2015-2018	INTERREG IVC	Y				
Smartaxi	Innovative customer forecasting system with 32% savings in Taxi operational costs	2016-2017	H2020-EU.3.4.		Y			

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
SMARTFUSION	Smart Urban Freight Solutions	2012-2015	FP7-TRANSPORT		Y			
SmartWASTE	Smart logistics for WASTE and recycling operations in European cities	2016-2018	H2020-EU.3.4.		Y			
SocialCar	Open social transport network for urban approach to carpooling	2015-2018	H2020-EU.3.4.	Y				
SOLUTIONS	Sharing Opportunities for Low carbon Urban TransporTatION	2013-2016	FP7-TRANSPORT	Y				
SOUTHPARK	SOUTHPARK - SOcial and Universal Technology for searcHing local PARKing space	2015-2017	H2020-EU.3.4.	Y				
SPICE	Support Procurements for Innovative transport and mobility solutions in City Environment	2016-2018	H2020-EU.3.4.	Y				
SPIDER PLUS	Sustainable Plan for Integrated Development through the European Rail Network Projecting Logistics & Mobility for Urban Spatial Design Evolution	2012-2015	FP7-TRANSPORT				Y	
ST4RT	Semantic Transformations for Rail Transportation	2016-2018	H2020-EU.3.4.				Y	
SUCCESS	Sustainable Urban Consolidation CentrES for conStruction	2015-2018	H2020-EU.3.4.		Y			
SURVEIRON	Advanced surveillance system for the protection of urban soft targets and urban critical infrastructures	2016-2018	H2020-EU.3.7.					Y

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
TAG	Crowd-Sourcing technology to change how people and cars move in cities	2015-2017	H2020-EU.3.4.	Y				
TIDE	Transport Innovation Deployment for Europe	2012-2015	FP7-TRANSPORT		Y			
TiMMi Transport	Making CO2-free city logistics a reality	2018-2018	H2020-EU.2.1.		Y			
TownHall24	A 24/7 platform providing access to services for isolated communities and reduced mobility residents	2017-2017	H2020-EU.3.4.	Y				
TRACE	Opening the cycling and walking tracking potential	2015-2018	H2020-EU.3.4.	Y				
TRACKER	Smart tracking of air pollution by a bike light	2017-2017	H2020-EU.3.4.	Y				
TrafficWise	Transforming Cellular Network Data Into the Next Generation of Mobility Management Platform	2016-2018	H2020-EU.3.4.		Y	Y		
TRAINSFARE	Smart tool to protect public transport revenues, assets, passengers and mobility	2017-2019	H2020-EU.3.4.		Y			
TRAINSFARE	Transport System with Artificial Intelligence for Safety and Fare Evasion	2015-2015	H2020-EU.3.4.		Y			
TRAMAN21	Traffic Management for the 21st Century	2013-2017	FP7-IDEAS			Y		
TRUST	TRUck Sustainable Transport - Innovative project for management of Contract Logistics	2017-2017	H2020-EU.3.4.		Y			

Project acronym	Project name	Project duration	Source of funding	Sustainable & integrated smart mobility	Design of effective operating models	Digital infra-structure	Future inter-modality	Air and virtual mobility
UDRIVE	eUropean naturalistic Driving and Riding for Infrastructure & Vehicle safety and Environment	2012-2016	FP7-TRANSPORT			Y		
U-TURN	Rethinking Urban Transportation through advanced tools and supply chain collaboration	2015-2018	H2020-EU.3.4.		Y			
VIAJEO PLUS	International Coordination for Implementation of Innovative and Efficient Urban Mobility Solutions	2013-2016	FP7-TRANSPORT		Y			
VitalNodes	Building a lasting expert network that delivers evidence-based recommendations for Vital Urban Nodes along TEN-T Corridors	2017-2019	H2020-EU.3.4.	Y				
VRUITS	Improving the Safety and Mobility of Vulnerable Road Users through ITS applications	2013-2016	FP7-TRANSPORT	Y				
WOOLF	An advanced and wearable solution to increase motorcyclists? Safety	2017-2018	H2020-EU.3.4.			Y		
XCYCLE	Advanced measures to reduce cyclists' fatalities and increase comfort in the interaction with motorised vehicles	2015-2018	H2020-EU.3.4.	Y				

Annex 2. Scopus database regular expression analysis keywords

REGEX keywords:

Smart mobility

TITLE-ABS-KEY ("smart mobility") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

Carpooling (and ridesharing)

TITLE-ABS-KEY ("carpooling") OR TITLE-ABS-KEY ("car pooling") OR TITLE-ABS-KEY ("ride sharing") OR TITLE-ABS-KEY ("ridesharing") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

Car-sharing

TITLE-ABS-KEY ("carsharing") OR TITLE-ABS-KEY ("car sharing") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

Mobility on demand and Mobility as a Service

TITLE-ABS-KEY ("mobility on demand") OR TITLE-ABS-KEY ("mobility as a service") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

Mobility data

TITLE-ABS-KEY ("mobility data") AND TITLE-ABS-KEY ("collection") OR TITLE-ABS-KEY ("management") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

Soft (and active) mobility

TITLE-ABS-KEY ("soft mobility") OR TITLE-ABS-KEY("active mobility") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

Drone (or Urban air) mobility

TITLE-ABS-KEY ("urban air mobility") OR TITLE-ABS-KEY ("drone mobility") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

(mobility) Living Labs

TITLE-ABS-KEY ("living lab") AND TITLE-ABS-KEY ("mobility") and (PUBYEAR > 2009) AND (PUBYEAR < 2020)

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