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Research and innovation in network and traffic management systems in Europe

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

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Contents

Abstract

Adequate research and innovation (R&I) is paramount for the seamless testing, adoption and integration of network and traffic management systems. This report provides a comprehensive analysis of R&I initiatives in Europe in this field. The assessment follows the methodology developed by the European Commission's Transport Research and Innovation Monitoring and Information System (TRIMIS). The report critically addresses research by different thematic areas 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 network and traffic management systems (NTM) in Europe in the last years, focusing on European Union (EU) funded projects. It identifies progress in several thematic fields and technologies, while highlighting the policy context and market activities in Europe and beyond.

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[1,2] which highlights key transport R&I areas and priorities for clean, connected and competitive mobility, under seven roadmaps. The STRIA roadmaps set out common priorities to support and speed up the research, innovation and deployment process leading to technology changes in transport.

In May 2018, the EC revealed the third Mobility Package with the objective to allow citizens to benefit from safer traffic, less polluting vehicles and more advanced technological solutions, while supporting the competitiveness of the EU industry[3]. Particular focus is given to network and traffic management systems[4].

The STRIA roadmap for NTM was published in November 2016[5]. NTM systems are an essential element for infrastructure and traffic managers to provide relevant information to transport users and to optimise the management of the transport network. NTM systems collect information from heterogeneous sources on the condition of the transport network. Based on this, they are used to provide information, guidance or operating instructions to transport users based on algorithms and protocols that ensure safe and optimised use of the transport infrastructure both in normal and in emergency situations. To this end, NTM systems are composed of a set of applications and management tools that integrate communication, sensing and processing technologies.

Although NTM systems are predominantly used to optimise travel times and improve safety, they are increasingly being leveraged to reach other objectives such as air quality in urban areas. There is also a slow shift away from vehicle-based traffic management towards multi-modal network management covering all modes of transport. Such an integrated approach requires the interoperability of different technologies but also the integration of different business models and collaboration among the infrastructure managers, the main transport operators and other stakeholders.

This report aims to provide a clearer picture on the state of play in NTM research. These results should help funding organisations, policy makers and researchers to make better informed choices to push the field forward. The analysis is split among six sub-themes that were found to be pertinent in literature and research: (i) traffic management systems, (ii) air traffic management, (iii) intermodal management systems, (iv) travel hub management, (v) freight transport & logistics, and (vi) sensors and detection systems. These sub-themes address challenges and findings across modes, including multi-modal transport. The analysis is primarily based on the European Commission's Transport Research and Innovation Monitoring and Information System (TRIMIS).

Main findings and conclusions

Benefits of NTM research

— The benefits of NTM are considerable with studies showing positive examples for each mode of transport:

- Road: Benefit-cost ratios ranging from 2 to 8 for implementing C-ITS systems across the EU.
- Aviation: Around EUR 12 billion performance gains for an investment of about EUR 4 billion in the period 2015 – 2024.

1 Commission staff working document — Towards clean, competitive and connected mobility: the contribution of transport research and innovation to the mobility package, SWD(2017) 223, Brussels.

2 Europe on the move - An agenda for a socially fair transition towards clean, competitive and connected mobility for all, COM(2017) 0283 final, Brussels.

3 Europe on the move - Sustainable Mobility for Europe: safe, connected, and clean COM/2018/293 final

4 Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee, The Committee Of The Regions, On the road to automated mobility: An EU strategy for mobility of the future COM/2018/283 final

5 https://trimis.ec.europa.eu/sites/default/files/stria_roadmap_-_network_and_traffic_management_systems_0.pdf

- Rail: A positive business case for the implementation of ERTMS on the core network corridors.
- Waterborne: Optimised travel planning and a strong reduction in inefficient anchoring time.

— These benefits are a key rationale for supporting NTM through R&I funding.

Overview on European NTM Research funding

By analysing two key funding programmes, the following findings could be retrieved:

— Under FP7 and H2020 over EUR 1.95 billion has been invested in NTM research projects. This includes EUR 1.3 billion of EU funds and about EUR 0.6 billion of own contributions by beneficiary organisations.

— A total of 2 335 unique organisations participated in FP7 and/or H2020 projects on NTM. Some organisations focus exclusively on NTM research in one mode of transport, whereas others conduct research across modes. Of the top 15 beneficiaries, all are active in aviation, 4 in road, 5 in multimodal, 5 in rail, and 4 in waterborne transport.

— Spending on NTM research under H2020 peaked in the beginning of 2018. Aviation research received most funding, while waterborne transport received the smallest amount of funds.

— The technology analysis highlights clusters that are researched in FP programmes at different development phases.

— The text analysis on scientific research showed that the number of publications in NTM generally shows a positive trend, with the keyword ITS receiving most interest.

Project related findings by sub-theme

There are several findings that can be derived from past research projects.

On the traffic management systems sub-theme:

— The majority of projects are at the early basic research stage of development, with several also at the demonstration and implementation phases. Funding for the projects under this sub-theme has been provided by SME-1 (for several, relatively small, projects) and RIA (for larger basic research projects), reflecting the early stages of development of the majority of projects at inception, as well as other actions that have supported taking the technologies through towards demonstration and implementation.

— Safety is a key foundation for several projects under this sub-theme. For example, CONTAIN, which also falls under the sub-theme on freight transport and logistics, aims to enhance security and safety in container management. As safety remains a key theme for EU-funded projects, as well as a key objective for EU-level policy, it is important that future research continues to develop innovative solutions to improving the safety of transport networks across all modes.

— Although the majority of projects under this sub-theme are funded by H2020 and FP7, CEF is the key funding instrument implementing TEN-T policy in Europe. This includes ITS for road and ERTMS for railways, which relate to connectivity and traffic management in road and rail transport, respectively. The next CEF programme (2021-2027) is expected to focus on making transport more connected, sustainable, inclusive, safe and secure, which aligns with the current themes of the projects explored. Therefore, as the CEF programme develops, it is expected that funding for demonstration and largescale testing projects will support innovation across the key thematic areas of safety, sustainability and traffic optimisation.

On the air traffic management (ATM) sub-theme:

— The majority of projects are at the early basic research stage, with several also at the validation phase. Therefore, the vast majority of projects which fall under this sub-theme explore new technologies for advancing ATM, with few projects focusing on the implementation of existing concepts. The majority of projects are currently funded under the RIA action.

— Several projects focus on improving risk management and safety. Some of these projects include demonstrations of technologies developing during the project, to test the capacity of new systems to accurately and effectively improve safety across the span of air traffic operations. Therefore, bringing these technologies to fruition, upon successful demonstration through the CSA (for coordination projects) and IA (for more mature research projects) actions, will provide an impactful contribution to aviation safety.

On the intermodal management systems sub-theme:

- The majority of projects are at the early research stage, with a few project technologies at the demonstration phase. This is largely reflected in the funding actions, with the majority of projects being funded by SME-2 and RIA.
- In attempts to encourage a modal shift, projects focused on developing digital solutions to enhance the attractiveness of rail transport as a mode of travel. These projects aim to enhance interoperability and shift the transport system to a lower carbon pathway. Further research could facilitate the advancement of these technologies from research to demonstration and implementation.
- The legal framework for the deployment of ITS and advanced NTM systems in the road sector is provided by the ITS Directive. The Directive aims to ensure the compatibility, interoperability and continuity of ITS solutions across the EU and sets out a number of policy measures to support the accessibility of EU-wide multimodal travel information for ITS users. Therefore, comprehensive EU-level funding is in place to drive research into intermodality forwards.

On the travel hub management sub-theme:

- The majority of projects are at the early basic research stage, with several also at the validation, demonstration and implementation phases. This is reflected in the funding actions, with almost all of the projects funded under the SME-1, SME-2 and RIA funding actions.
- Travel hub management possesses strong links with multimodality, particularly in cities. Several of the projects take place in urban environments, aiming to enhance the effectiveness and sustainability of transport hubs and interchanges in cities. As the majority of these projects are still in the early stages of development, future research would be beneficial to understand the effective operation of urban transport networks by increasing the capacity of city interchanges to facilitate efficient transport and encouraging increased multimodality, under IA and CSA funding actions.
- CEF represents the overarching funding instrument for transport infrastructure projects, offering support for transport systems across all modes. Therefore, funding is in place to support developments of travel hubs. As cities continue to aim to shift towards more sustainable modes of transport, policy at the city-level will be important, to ensure that the foundations are in place to support the development of safe and sustainable city interchanges.

On the freight transport and logistics sub-theme:

- The majority of projects are at the early basic research stage, with a few projects also at the demonstration and implementation phases. This is reflected in the funding actions driving this research forwards, as SME-1 and RIA are the primary funding actions, which assist with the basic research and validation of technologies.
- The projects focusing on logistics are varied in nature, yet a focus on sustainability is a common foundation for several projects. Beyond sustainability, a key focus for the logistics industry is the development of intelligent systems which support intermodality, with the capacity to be adopted across Europe.
- The vast majority of the projects under this sub-theme focus on multimodal travel, with minimal focus on rail freight. In regard to multimodality, the majority of projects focus on collaborative logistics ecosystems, which attempt to enhance efficiency and cohesion between multiple modes. These projects are almost entirely at the basic research development phase, requiring additional funding to bring promising technologies to the validation and demonstration stages. A focus on multimodal travel is followed by road and waterborne logistics. Research into rail transport under this sub-theme is relatively small.

On the sensors and detection systems sub-theme:

- The majority of projects are at the early basic research stage, with several also at the demonstration phase (and a few at the validation and implementation phases). This is reflected in the funding actions supporting these projects, with the majority of projects falling under the SME-1 funding action.
- Under this sub-theme the use cases vary significantly and span across all modes of transport. However, air transport has been allocated the most significant number of projects, including both aviation and drone technologies.

— A series of projects have focused on applying existing satellite systems, such as LOGIMATIC, which aimed to advance port vehicle automation through making use of navigation technologies. As the majority of projects are still at the early development phases, further research which could bring these applications to demonstration and implementation phase could be valuable.

The analyses performed in this report are subject to some limitations, namely:

— TRIMIS focuses on publicly funded projects, therefore private initiatives are not fully considered. This makes that the report provides a distinctive perspective on transport R&I.

— On Section 5, the technology identification and the corresponding development phase assessment is still on going, and the technology taxonomy is being updated. Likewise, the methodology behind the text analysis on NTM academic research shall be improved.

Altogether, this report provides a comprehensive and up-to-date review of NTM R&I across Europe. These findings can be leveraged by various actors that are involved in shaping the future of research on network and traffic management systems.

Related and future JRC work

This report on R&I in NTM 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 on patents and publications will be added. TRIMIS will continue to provide support to STRIA and, on the basis of its research, provide recommendations to policymakers.

Quick guide

The report is structured in the following manner:

Section 1 gives a brief introduction and background on NTM research. Section 2 provides the scope of the report together with a methodological background. Section 3 provides the market context and Section 4 the policy context. Section 5 highlights NTM related project statistics, a quantitative assessment of the technologies in framework programmes and some insights from international academic research on NTM. Section 6 provides the R&I assessment of specific NTM projects, dividing NTM research in six sub-themes. Finally, Section 7 presents the conclusions.

1 Introduction

The transport sector needs to evolve to tackle numerous environmental and socio-economic challenges. Research and innovation (R&I) contributes to this process and enables new quality standards in the transport of people and goods.

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; 2017b), which highlights main transport R&I areas and priorities for clean, connected and competitive mobility. The STRIA roadmaps set out common priorities to support and speed up the research, innovation and deployment that leads to technology changes in transport. Seven STRIA roadmaps have been developed covering various thematic areas, namely:

- Connected and automated transport;
- Transport electrification;
- Vehicle design and manufacturing;
- Low-emission alternative energy for transport;
- Network and traffic management systems;
- Smart mobility and services; and
- Transport infrastructure.

The ECs Joint Research Centre (JRC) has developed the Transport Research and Information Monitoring and Information System (TRIMIS) to support the implementation of STRIA. TRIMIS maintains a database with about 7500 publicly funded transport research projects in early 2020, and publishes several analytical reports based on the database other data sources.

This TRIMIS report assesses R&I in network and traffic management systems (NTM). It provides a comprehensive analysis of general research trends and the outcomes of specific R&I projects under six key sub-themes, namely:

- Traffic management systems: focuses on projects which develop and implement traffic management systems in road, rail and waterborne transport.
- Air traffic management: focuses on projects which develop and implement technologies to improve air traffic management (ATM).
- Intermodal management systems: focuses on the development of intermodal management systems, both for freight and passenger transport.
- Travel hub management: focuses on projects which develop systems for effective travel hub management.
- Freight transport and logistics: focuses on projects which aim to enhance the efficiency of freight and logistics.
- Sensors and detection systems: focuses on the use of innovative sensors, radars and other detection systems to improve traffic management.

The provided insights assist funding organisations to identify opportunities for research and streamline R&I activities. Furthermore, policy makers may draw inspiration from the report's findings to understand the potential impacts of upcoming NTM technologies.

2 Methodological background

The main goal of this report is to thoroughly review EU funded NTM projects. To do so, three actions were necessary, namely:

1. The development and maintenance of the TRIMIS database.
2. The development of a methodology for the identification and assessment of the technologies researched within the NTM projects.
3. The conceptual framing for the project assessment.

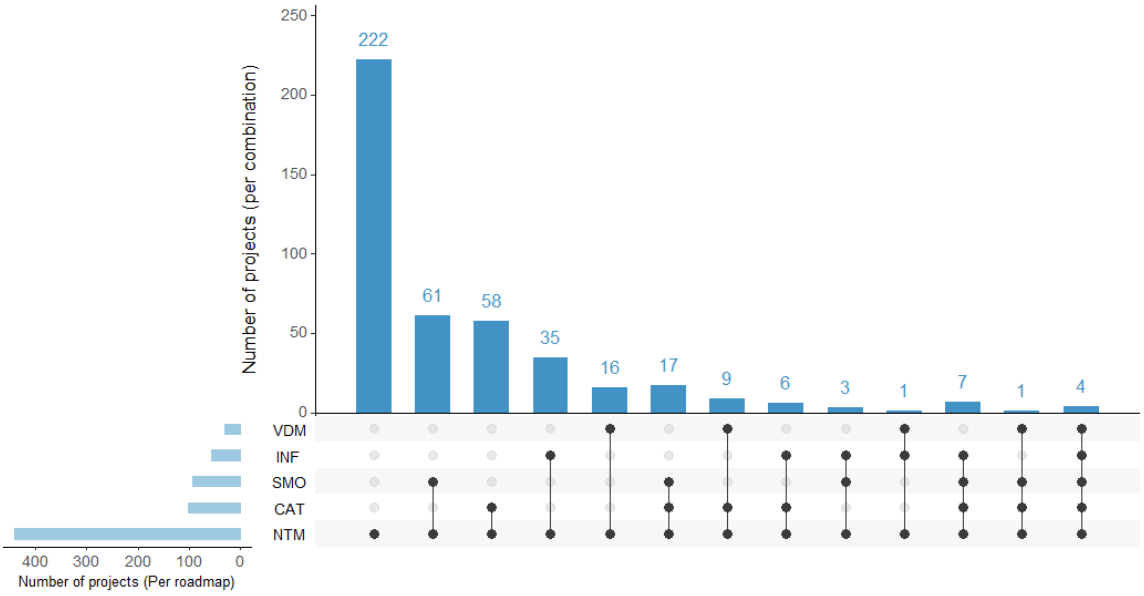
A brief description of these steps is provided in the following paragraphs. The chapter ends with an overview on the scope of each section to facilitate a better interpretation of the results.

2.1 Database development and labelling

TRIMIS hosts a continuously updated database of EU and MS programmes and projects (currently over 7 000) on transport R&I. Projects funded by the European FPs are retrieved through an automated data interchange with the Community Research and Development Information Service (CORDIS), while projects funded by MS are inserted manually by national contact points. Projects are then evaluated and labelled on several dimensions, after which they are published on TRIMIS (van Balen et al., 2019a).

A central step is to identify those projects that fall under the NTM roadmap. The scope of NTM was defined by the original STRIA roadmap. Based on this understanding, several transport specialists used machine learning algorithms and manual validation to label the projects[6]. Considering that many projects cover NTM dimensions to some extent, only those projects that cover a considerable NTM research component in the project description were assigned to the NTM roadmap. In such a case, a project can also be assigned to multiple roadmaps. An overview on the extent to which NTM projects overlap with other roadmaps depicted in Figure 1, based on 440 FP7 and H2020 projects, 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).

Figure 1. Overlap NTM projects with other STRIA roadmaps



(*) Alternative Energy (ALT); Electrification (ELT); Vehicle Design & Manufacturing (VDM); Connected & Automated Transport (CAT); Smart Mobility (SMO), Network & Traffic Management (NTM), Infrastructure (INF).

Source: TRIMIS

[6] The specialists also assessed the projects on several other variables, including the mode of transport and geographical focus of the project. Through discussions and interrater reliability assessments, the quality of the labelling is assured.

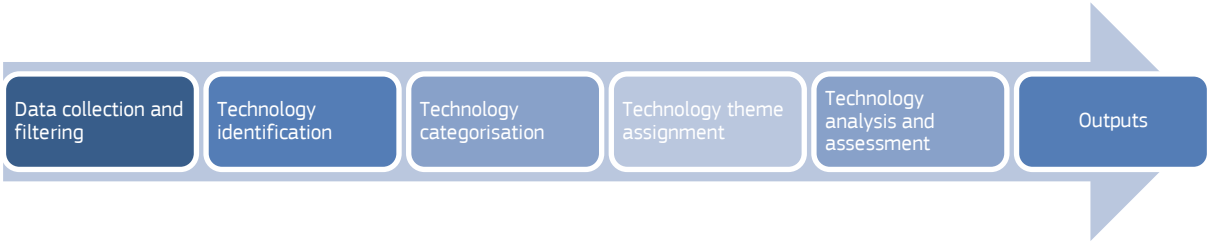
As the figure suggests, some projects are cross-cutting and include elements of other STRIA roadmaps as well. The overlaps should be taken into consideration when interpreting the results that are provided in this report.

2.2 Identification and assessment of the technologies researched within FPs

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). In doing so, a taxonomy, assessment and monitoring framework is proposed (Gkoumas and Tsakalidis, 2019) which supports innovation management at various levels, thus providing insights to the sector's stakeholders (i.e. researchers, business operators, national authorities and policymakers) while backing the current transport systems' transformation through technological advances.

The TRIMIS NETTs analysis currently focuses on technologies researched in European FP, specifically FP7 and H2020 projects from the TRIMIS database. Figure 2 presents an overview of the methodological steps undertaken.

Figure 2. Technology assessment methodological steps



Source: TRIMIS

In total, 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 these discussions, 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 like, for instance, those that encourage collaboration between different infrastructure managers. Once a technology was flagged in the project description, another researcher would validate the flagging and write down 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 subsequently 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.

In a final step, all projects were assessed on whether they focused on NTM. 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 is considered to be transparent and appropriate in the absence of technology-budget reports.

In a consequent step, a set of metrics was established to assess the 72 technologies identified within the NTM 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 the data in TRIMIS, recent programmes that have funded research in NTM topics have been identified. All related projects within the last two framework programmes (FP7 and H2020) have been included. In this report, each section considering the research performed under one of the sub-themes includes a table of projects considered during the review of that sub-theme.

Table 1 reports the sub-themes identified (left column), and the focus of each sub-theme (right column).

Table 1. NTM sub-themes

Sub-theme	Sub-theme focus
Traffic management systems	Projects which develop and implement traffic management systems in road, rail and waterborne transport.
Air traffic management	Projects which develop and implement technologies to improve air traffic management (ATM).
Intermodal management systems	Projects which develop intermodal management systems, both for freight and passenger transport.
Travel hub management	Projects which develop systems for effective travel hub management.
Freight transport and logistics	Projects which aim to enhance the efficiency of freight and logistics.
Sensors and detection systems	Projects which develop innovative sensors, radars and other detection systems to improve traffic management.

Source: TRIMIS

By adopting a 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 addresses NTM R&I from a complementary perspective, with a research scope that is adjusted accordingly. Table 2 highlights the approaches used in various parts of the report to facilitate understanding and interpreting the results.

Table 2. 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 2005 and 2019
Chapter 6: Qualitative analysis	Project reviews	In-depth analysis of FP7, H2020 and CEF projects that commenced between 2012 and 2019

Source: TRIMIS

3 State of play of network and traffic management systems

NTM systems are an essential element for infrastructure and traffic managers to provide relevant information to transport users and to optimise the management of the transport network. NTM systems collect information from heterogeneous sources on the condition of the transport network. Based on this, they are used to provide information, guidance or operating instructions to transport users based on algorithms and protocols that ensure safe and optimised use of the transport infrastructure both in normal and in emergency situations. To this end, NTM systems are composed of a set of applications and management tools that integrate communication, sensing and processing technologies.

Although NTM systems are still predominantly used to optimise travel times within a safe environment, they are increasingly targeting other objectives such as air quality in urban areas. There is also a slow shift away from vehicle-based traffic management towards multi-modal network management covering all modes of transport. Such an integrated approach requires the interoperability of the different technologies but also the integration of different business models and collaboration among the infrastructure managers, the main transport operators and other stakeholders.

In road transport, core services of NTM include strategic corridor and network management, section control (especially for sensitive road segments), incident management, speed control, ramp metering and hard shoulder running. Urban mobility applications also include public transport prioritisation, urban access restrictions, lane management, parking guidance, signal control and traffic information[7]. Large schemes of bus priority infrastructure (over 2 km), for example, can be found in Dublin, while smaller schemes in some sections have been implemented in Barcelona, London and Paris[8]. Several commercial solutions for advanced urban traffic optimisation are now available on the market. Based on multiple sources of information, including real-time traffic, air quality, smart parking and connected vehicle data, they deliver adaptive signal control with real-time predictive modelling. These advanced traffic optimisation systems can be tailored to specific traffic and mobility policies, including, for example, environmental targets, smoothing traffic flow on key routes, prioritisation of public transport or stimulating cycle flows. As an example, London has recently announced a substantial upgrade of its traffic light control system, supporting a range of new data sources, including sharing data with connected vehicles, which could include autonomous vehicles in the future[9].

Traditionally, NTM have monitored and helped infrastructure managers manage road traffic from a macroscopic point of view because data is collected in an aggregated way (e.g. traffic counters) and the information channel is the same for all road users (e.g. roadside information panel). However, cooperative intelligent transport systems (C-ITS) and upcoming connected and automated driving allow for the collection of enriched vehicle data with additional attributes (e.g. headway, traction information, brake status, hard braking, activation of emergency lights) and for direct interaction between the infrastructure (e.g. traffic control centre) and the vehicle's control intelligence. This may lead to the development of NTM protocols and algorithms in a microscopic fashion and ultimately to the development of cooperative traffic management systems. This may include, for example, roadside units collecting and exchanging local information with vehicles within a road section and enabling a decentralised traffic control strategy[10].

Connected vehicles integrated within C-ITS communicate with other vehicles (known as vehicle-to-vehicle (V2V) communication), with infrastructure (vehicle-to-infrastructure (V2I) communication) and with other road users such as cyclists or pedestrians (vehicle-to-everything (V2X) communication) using on-board sensors and internet connectivity. Vehicle connectivity applications currently being implemented and tested either use the Wi-Fi-based standard 802.11p (ITS-G5 in the EU) or cellular V2X technologies, such as the new LTE-V2X

[7] CIVITAS (2015), Intelligent Transport Systems and traffic management in urban areas, available at: https://www.eltis.org/sites/default/files/trainingmaterials/civ_pol-not6_its_web.pdf

[8] Mundy, D., at al. (2017), The identification and management of bus priority schemes, A study of international experiences and best practices, Imperial College London, available at: https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/centre-for-transport-studies/rtsc/The-Identification-and-Management-of-Bus-Priority-Schemes---RTSC-April-2017_ISBN-978-1-5262-0693-0.pdf

[9] https://tfl.gov.uk/info-for/media/press-releases/2018/june/delivering-the-next-generation-of-urban-traffic-management

[10] Gueriau, M. et al. (2016), How to assess the benefits of connected vehicles? A simulation framework for the design of cooperative traffic management strategies, Transportation Research Part C, 67, pp. 266-279, available at: https://hal.archives-ouvertes.fr/hal-01298573/document

standard or the forthcoming 5G. Member States and the industry are rather divided in terms of this technology choice[11].

According to the 'Study on the Deployment of C-ITS in Europe'[12], in front-runner countries, 100 % deployment of roadside C-ITS sub-systems is expected by 2026 along the Core TEN-T Network. The expected penetration rate drops to 20 % on non-urban non-motorway roads. The same study showed that the deployment of C-ITS is clearly beneficial at an EU level, with benefit-cost ratios (BCRs) ranging from 2-8 achieved in 2030 for the full range of deployment scenarios and sensitivities. Cumulative costs to 2030 are basically composed of the costs of the hardware required to support the deployment of C-ITS services to vehicles (86 %) and aftermarket devices (10 %), while cumulative benefits are composed of reduced travel times/increased efficiency (66 %), reduced accident rates (22 %) and fuel consumption savings (11 %).

In rail transport, the European Rail Traffic Management System (ERTMS) is a major industrial programme to harmonise automatic train control and communication systems and ensure interoperability throughout the rail system in Europe. The deployment of ERTMS will provide the backbone for a digital, connected Single European Rail Area (SERA) and enable the introduction of innovative technologies in an effective manner. According to ERRAC's Rail Vision 2050 report[13], the next generation of the ERTMS and mass transit communication-based train control (CBTC) will include combinations of autonomous, intelligent and highly responsive vehicles that are able to communicate with each other and with the intelligent infrastructure.

Under the ERTMS umbrella, advanced train control standards (e.g. ETCS) and communication standards (e.g. GSM-R) are increasingly deployed in the European rail network to ensure an interoperable Automatic Train Protection (ATP) system. In Europe, around 25 000 km of tracks are equipped or contracted today with ERTMS (Level 1 and/or 2)[14], 4 500 km of which are operational on core network corridors. Nearly the totality of the Italian and Spanish high-speed networks is supervised and protected by ERTMS; so are significant parts of the Swiss, Dutch and Belgian networks[15]. ERTMS is also deployed beyond European borders, with 95 589 km of ERTMS (Level 1 and/or 2) worldwide, 11 026 km of which is in China.

Despite the progress made, the rail traffic control systems deployed so far do not yet constitute an interoperable system. Before the appointment of the European Union Agency for Railways (ERA) as the prime authorising and certification authorities, barriers to full interoperability were different engineering rules within and between Member States, inefficiencies in conformity assessments and authorisation, and market inefficiencies, which led to uncoordinated deployment of ERTMS trackside and diverging requirements for on board units (OBUs)[16].

According to a recent business case analysis[17], ERTMS deployment on the nine core network corridors shows that there is a positive business case, with an overall internal rate of return (IRR) of 9.6 % over the period 2015-2050. Costs are composed of track-side deployment costs, rolling stock retrofitting costs and the upgrade costs for the rolling stock already equipped with ETCS. Main benefits are linked to the decrease of purchase and maintenance of the rolling stock, decrease of maintenance costs of the infrastructure, safety, increased capacity and reliability.

RNE (Rail Net Europe), an association of European rail infrastructure managers, develops and coordinates improvements in the field of traffic management for railways. An example of this cooperation is the Estimated Time of Arrival (ETA) Programme, which aims to improve the accuracy of ETA for international trains by helping infrastructure managers to take into account the time of handover of their neighbour infrastructure managers. This involves a standard and regular exchange of forecast data from the Train Information System between neighbouring infrastructure managers.

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[11] This technology choice and its interoperability with the communication infrastructure has been a key element of the discussion on the Delegated Regulation on Cooperative Intelligent Transport Systems (C-ITS). See, for example, GSMA-ETNO (2019) Letter on safe and competitive Connected and Automated Driving in Europe, available at: https://www.gsma.com/gsmaeurope/wp-content/uploads/2019/04/GSMA-ETNO-Letter-on-safe-and-competitive-Connected-and-Automated.pdf

[12] Study on the Deployment of C-ITS in Europe: Final Report, available at: https://ec.europa.eu/transport/sites/transport/files/2016-c-its-deployment-study-final-report.pdf

[13] ERRAC (2017), RAIL 2050 VISION, available at: https://errac.org/wp-content/uploads/2019/03/122017_ERRAC-RAIL-2050.pdf

[14] http://www.ertms.net/?page_id=58

[15] European Commission (2017), ERTMS Deployment Action Plan, available at: https://ec.europa.eu/transport/sites/transport/files/2017-ertms-deployment-action-plan.pdf

[16] European Commission (2017), ERTMS Deployment Action Plan, available at: https://ec.europa.eu/transport/sites/transport/files/2017-ertms-deployment-action-plan.pdf

[17] European Commission (2019), ERTMS business case on the 9 core network corridors – Second release, available at: https://op.europa.eu/en/publication-detail/-/publication/a5c88a67-994f-11e9-9d01-01aa75ed71a1

In air transport, an air traffic management (ATM) system is the aggregation of the airborne and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations. The Single European Sky ATM Research (SESAR) Programme is the technological pillar of the Single European Sky initiative, which aims at modernising ATM and de-fragmenting European airspace. SESAR aims to transform European air traffic management into a more modular, automated, interoperable, flight- and flow-centric system that takes advantage of advances in digital and virtualisation technologies.

Since 2008, the SESAR Joint Undertaking (JU) has commissioned research that has validated and delivered more than 60 SESAR solutions, which are being implemented either to answer local needs or in a coordinated way under the EU's Pilot Common Project (PCP). According to the SESAR deployment programme, the PCP is expected to deliver around EUR 12.1 billion in performance gains, for an investment of EUR 3.8 billion between 2015 and 2024, with potential annual benefits to the aviation sector of up to EUR 15 billion per annum beyond 2035. Expected benefits are essentially in terms of capacity (savings in flight delays), environment (savings in tonnes of CO_2), and operational efficiency (savings in flight time).

Eurocontrol's 'Challenges of Growth' report[18] estimates that air traffic in Europe is likely to grow to just over 16 million flights by 2040, which represents a 53 % growth with respect to 2017 levels. In response, European airports are planning a 16 % increase in capacity on average, which translates into four million more runway movements. However, this capacity expansion will be insufficient as it may leave 1.5 million flights unaccommodated by 2040 and lead to increased congestion levels, with the average delay per flight in the summer increasing from 12 minutes in 2016 to 20 minutes in 2040. The report estimates that the successful deployment of SESAR Wave 1 at busy airports could reduce the most likely capacity gap by 28 % in 2040.

In terms of air transport user information, a number of commercial flight information displays or flight trackers are now available on the market. These allow passengers to visualise real-time flight data and understand current flight conditions, including their status, weather conditions and other possible disruptions. The data can also be used by relevant stakeholders to analyse trends and performance of the air transport market.

Analogous to air transport, sea traffic management can be defined as the aggregation of the seaborne and shore-based functions (sea traffic services, maritime space management, and sea traffic flow management) required to ensure the safe and efficient movement of vessels during all phases of operation. However, maritime traffic management in open seas is undertaken through a distributed control system, which means that all ships find their own way and conflicts are resolved locally[19]. Today, vessels' automatic identification systems (AIS) provide information about their location to other vessels and to coastal authorities automatically but it is not possible to deduce the routing intentions of vessels only from information received from the AIS.

In areas of high traffic-density (e.g. close to ports) support is provided by a vessel traffic service (VTS) to promote traffic safety and fluency. These are shore-side systems which range from the provision of simple information messages to ships, such as the position of other traffic or meteorological hazard warnings, to the extensive management of traffic within a port or waterway upon request. Although the notion of a distributed control system is highly embedded in maritime transport practice, sea traffic may benefit from an organising mechanism, especially in a context of increased activity.

The concept of sea traffic management (STM) has been developed during EU-financed research and innovation projects, starting with the MonaLisa project. STM seeks to create an organised traffic management entity called the Sea Traffic Coordination Centre (STCC) that will assist the route choice of vessels in an equivalent way to ATM for air transport[20]. An STM system requires a global exchange system for sea traffic information, such as the European SafeSeaNet, which integrates automatic identification system (AIS) data, ship Mandatory Reporting System (MRS) notifications, incident reports, port notifications and dangerous and polluting goods (HAZMAT) notifications.

[18] Eurocontrol (2018), European aviation in 2040: Challenges of growth, available at: https://www.eurocontrol.int/publication/challenges-growth-2018

[19] Van Westrenen, F., Praetorius, G. (2014), Maritime traffic management: a need for central coordination, Cogn Tech Work, 16:59-70, available at: https://link.springer.com/article/10.1007/s10111-012-0244-5

[20] https://www.stmvalidation.eu/

At the port side, a number of commercial solutions have emerged for optimising the complex traffic of vessels. These involve the exchange of planned, expected and realised times for vessels within a shared platform for shipping companies, agents, terminals and other service providers. This allows for a more efficient planning of the port call.

Similarly, in inland waterways transport, River Information Services (RIS) allow for a real-time exchange of harmonised information supporting traffic and transport management in inland navigation including electronic ship reporting, inland electronic navigational charts (IENCs), automatic identification system (AIS), notices to the skipper, and radar. This is a pre-requisite for traffic management services aiming at optimising the use of the infrastructure as well as facilitating safe navigation, especially at VTS centres, as well as at locks and bridges. A number of commercial applications are also available on the market to assist users to plan their routes more efficiently by providing real-time information on route conditions.

4 Policy context

4.1 Network and traffic management systems in European transport policy

Since 2014, the Connecting Europe Facility (CEF) is the funding instrument to support TEN-T policy objectives for transport infrastructure. The revised TEN-T Guidelines[21] adopt a 'dual layer approach' consisting of the core network, focused on strategic and major European transport flows, and the comprehensive network, focused on ensuring accessibility across all European regions. Time-wise, the core network is to be completed by the end of 2030 and the comprehensive network by 2050. Both layers incorporate infrastructure for all transport modes as well as other accompanying measures, including EU-wide ITS applications and NTM systems.

The CEF 2014-2020 programme has an overall budget of EUR 24.05 billion for transport. Around 80 % of this is allocated to infrastructure projects focused on the nine core TEN-T corridors, while the remaining 20 % is used to provide support to projects tackling horizontal priorities such as the deployment of traffic management systems for increasing the efficiency of existing infrastructure (e.g. ERTMS for railways, SESAR for aviation, ITS for road, RIS for inland waterways), and new technologies and innovations for transport decarbonisation (e.g. electrification, liquefied natural gas, intelligent transport systems)[22]. The next CEF programme 2021-2027 is expected to focus on decarbonisation and making transport connected, sustainable, inclusive, safe and secure. The budget would reflect this rebalancing: 60 % of transport resources would go to the development of basic infrastructure and 40 % to modernising the existing network, including the development of NTM systems[23].

In road transport, the next phase of the CEF is expected to support the 5G cross-border network. Member States and industry agreed to establish a network of cross-border corridors in September 2017. The objective of this network is to promote large-scale testing and early deployment of 5G infrastructure, enabling connected and automated driving, and improved NTM systems. Three 5G cross-border corridor projects covering more than one thousand kilometres of highways were launched in November 2018 with Horizon 2020 (H2020) funding.

The legal framework for the deployment of ITS and advanced NTM systems in the road sector is provided by the ITS Directive[24]. The Directive aims to ensure the compatibility, interoperability and continuity of ITS solutions across the EU and sets out a number of policy measures to support the accessibility of EU-wide multimodal travel information for ITS users. The Commission has recently been trying to reach an agreement with the other EU institutions on a Delegated Regulation supplementing the ITS Directive to facilitate the uptake of Cooperative Intelligent Transport Systems (C-ITS) across the EU[25].

According to the delegated acts[26] adopted under the ITS Directive, the data that is to be collected and supplied shall be accessible through national access points (NAPs) and use DATEX II as a data exchange standard. NAPs aim at facilitating easy access to, and the exchange and reuse of, transport-related data, and at supporting the provision of EU-wide interoperable travel and traffic services. An overview of the NAPs shows that their scope and set up varies a lot across Europe, with some Member States not having an operational NAP[27].

Road pricing schemes are also an essential management tool for road infrastructure managers. The latest review of the Eurovignette Directive[28] sets common rules on distance-related tolls and time-based infrastructure charges for heavy goods vehicles and allows the application of external cost charges related to noise and air pollution. To ensure interoperability between the different existing systems, Directive

[21] Regulation (EU) No 1315/2013

[22] European Parliament (2019), Research for TRAN Committee – EU funding of transport projects, available at: http://www.europarl.europa.eu/RegData/etudes/STUD/2019/629199/IPOL_STU(2019)629199_EN.pdf

[23] European Parliament (2019), Connecting Europe Facility 2021-2027 Financing key EU infrastructure networks, available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2018/628247/EPRS_BRI(2018)628247_EN.pdf

[24] Directive 2010/40/EU

[25] https://ec.europa.eu/transport/sites/transport/files/legislation/c20191789.pdf

[26] Commission Delegated Regulation (EU) No 885/2013; Commission Delegated Regulation (EU) No 886/2013; Commission Delegated Regulation (EU) No 962/2015; Commission Delegated Regulation (EU) 2017/1926

[27] European Commission (2019), National Access Points A mechanism for accessing, exchanging and reusing transport related data under Delegated Acts of the ITS Directive (2010/40/EU, available at: https://ec.europa.eu/transport/sites/transport/files/its-national-access-points.pdf

[28] Directive 2011/76/EU

2004/52/EC lays down the common conditions for electronic road toll systems and foresees a European Electronic Toll Service.

The 4th Railway Package released in 2016 is a set of six legislative texts designed to complete the SERA both for technical and market integration. The market pillar completes the process of gradual market opening by liberalising all types of passenger services. The technical pillar aims to reduce costs and administrative burdens for railway undertakings by ensuring interoperability and simplifying administrative procedures. In particular, this policy package empowers the European Union Agency for Railways (ERA) as the ERTMS system authority in order to maintain, monitor and manage the corresponding subsystem requirements.

In 2017, the European Commission published the ERTMS European Deployment Plan (EDP)[29], which lays down the timetable for the deployment of ERTMS trackside installations on nine core network corridors. The ERTMS EDP sets new targets until 2023 by which about 50 % of the core network corridors shall be equipped. In 2023, the ERTMS EDP will be updated again setting out the precise dates for the equipping of the remaining parts of the corridors, which is to be achieved between 2024 and 2030. The EDP requires full compliance with the technical specifications for interoperability control command and signalling (CCS TSI)[30], which is the legal basis of ERTMS specifications.

With regard to rolling stock, Commission Decision 2016/919 states that new vehicles authorised to be put into service for the first time shall be equipped with ERTMS and by 2019 any new vehicle to be equipped with ERTMS should implement 'Baseline 3' specifications, the more advanced set of system requirements.

In addition to CEF, as noted above, the other main instrument supporting the technical development of the ERTMS system is the Shift2Rail Joint Undertaking (S2R JU), which is a public-private partnership established in 2014 following the entry into force of Council Regulation 642/2014. The estimated budget of the S2R JU is around EUR 920 million (for the period 2014-2020) – EUR 470 million from the private sector and EUR 450 million from Horizon 2020 funds. One of the objectives of S2R JU, under its Innovation Programme 2, is to keep ERTMS technology ahead of the competition and to enhance the interoperability of traffic management and control systems across the EU rail network, including urban rail networks (i.e. CBTC).

The Single European Sky (SES) is an ambitious initiative launched by the European Commission in 2004 to enhance current air traffic safety, to contribute to the sustainable development of the air transport system and to improve the overall performance of ATM and air navigation services. The four Regulations adopted in 2004[31] (the SES I Package) were revised and extended in 2009 with Regulation 1070/2009 focusing on environment and cost efficiency (the SES II Package). The SES performance objectives aim at tripling capacity, reducing ATM costs by half, improving safety by a factor of 10 and reducing the environmental impact of each flight by 10 %. However, complete implementation of the SES is challenging given the resistance from many EU countries, often driven by social concerns[32].

The SESAR Programme is the technological pillar of the SES and is divided into three phases: definition, development and deployment. The definition phase produced the first edition of the European ATM Master Plan in 2008, which was subsequently updated in 2012 and in 2015. The Master Plan is an evolving roadmap that sets the priorities in R&D activities and solutions to achieve the vision and performance ambitions for the future ATM system.

The development phase is managed by the SESAR Joint Undertaking (SESAR JU), which was created by Council Regulation 219/2007[33]. The SESAR JU is funded by the European Union, Eurocontrol and industry partners, each of which contribute one third to the total funding. The EU contribution to the SESAR 1 Programme (2008-2016) was provided under FP7 and TEN-T funds, while SESAR 2020 Programme (2016-2024) is financially supported by the EU under Horizon 2020 mostly (EUR 585 million) plus additional contribution under CEF (EUR 10 million) and assigned revenues (EUR 1.3 million)[34].

[29] Commission Implementing Regulation (EU) 2017/6
[30] Commission Regulation (EU) 2016/919
[31] Regulations (EC) 549/2004, 550/2004, 551/2004, 552/2004
[32] DGMOVE (2019), Transport in the European Union: Current Trends and Issues, available at: https://ec.europa.eu/transport/sites/transport/files/2019-transport-in-the-eu-current-trends-and-issues.pdf
[33] The regulation has been amended twice, in 2008 (Regulation 1361/2008) and again in 2014 (Regulation 721/2014), when the duration of the SESAR JU was extended until 2024
[34] https://www.sesarju.eu/discover-sesar/funding

With the implementing Regulation establishing the SESAR deployment framework[35], the Commission activated the deployment phase. ATM functionalities requiring synchronised deployment and contributing significantly to Union-wide performance targets are included in the so-called Pilot Common Project[36], which is managed by the SESAR Deployment Manager as a partnership between airlines, airports and air navigation service providers.

In the maritime sector, the EU Maritime Information and Exchange system, SafeSeaNet, was established in accordance with the Vessel Traffic Monitoring & Information Systems (VTMIS) Directive[37], amended by Directive 2014/100/EU. SafeSeaNet is set up as a network for maritime data exchange, linking together maritime authorities from across Europe through an internet-based system with distributed databases. The SafeSeaNet central node is managed and operated by the European Maritime Safety Agency (EMSA). Under the SafeSeaNet Ecosystem Graphical User Interface (SEG), EMSA integrates within a common web interface SafeSeaNet data (including radio-based AIS) with information on other vessel traffic reports (satellite-based LRIT), satellite monitoring (CleanSeaNet), and Port State Control (Thetis).

Regarding freight and legal data, the Reporting Formalities Directive (RFD)[38] requires that reporting obligations for ships arriving in and departing from EU ports should be transmitted electronically via the so called 'national single window' interface. Given the limited effect of this Directive and in line with the ambition to establish a real European maritime transport space without barriers ('Blue Belt'), the Commission has proposed a regulation establishing a European Maritime Single Window environment (EMSWe)[39].

More broadly, in line with the aim of the White Paper on Transport 2011[40] to create an e-Freight framework to allow tracing goods in real time and ensure intermodal liability, the European Commission has recently proposed a regulation on electronic freight transport information[41]. The aim of this regulation is to provide for a fully digital and harmonised environment for information exchanges between transport operators and authorities.

In inland waterways transport, European transport policy supports RIS development by means of policy development, legislation and financial support. The EU RIS Framework Directive[42] provides minimum requirements to enable cross-border compatibility of national systems. In order to ensure harmonised development, the European Commission has published the RIS Guidelines, but also Regulations regarding all RIS key technologies (Vessel Tracking and Tracing (VTT), Notices to Skippers (NtS), Electronic Reporting International (ERI) and Inland Electronic Chart Display and Information System (Inland ECDIS)[43].

As with other traffic management systems, RIS implementation is financially supported under the Connecting Europe Facility (CEF), the Structural and Cohesion Funds, the Instrument for Pre-Accession Aid (IPA II), as well as the Horizon 2020 Programme.

4.2 Network and traffic management policies in non-European countries

In the US, a recent report[44] issued by the Federal Highway Administration (FHWA) highlights the potential of connected vehicle technology to enhance ITS solutions and NTM strategies related both to recurring and non-recurring congestion. This is expected to lead to advanced traffic management systems (ATMS) as traffic agencies gradually incorporate connected vehicle technology into their infrastructure, equipment and operations management.

The Department of Transport's (US DOT) current ITS Strategic Plan 2015-2019[45] is focused on two key priorities: realising connected vehicle implementation and advancing automation. Most of the research activities of this programme are handled by the different US DOT agencies (e.g. FHWA, FTA) but the

[35] Regulation 409/2013
[36] Regulation 716/2014
[37] Directive 2002/59/EC
[38] Directive 2010/65/EU
[39] COM(2018) 278
[40] COM(2011) 144
[41] COM(2018) 279
[42] Directive 2005/44/EC
[43] Regulations 414/2007, 415/2007, 416/2007, 164/2010, 689/2012, 909/2013
[44] Federal Highway Administration (2018), Effects on Intelligent Transportation Systems Planning and Deployment in a Connected Vehicle Environment, available at: https://ops.fhwa.dot.gov/publications/fhwahop18014/fhwahop18014.pdf
[45] https://www.its.dot.gov/strategicplan.pdf

programme is coordinated by the ITS Joint Program Office (JPO), which is comprised of programme managers and coordinators of the US DOT's multimodal ITS initiatives.

As part of the ITS programme, the US DOT has given $45 million to three pilot deployments of connected vehicle applications in New York City, Wyoming, and Tampa, including applications for the urban environment and freight transport. One of the key goals of these pilot deployments is to produce and provide open data for use by third-party researchers and developers. The ITS Data Hub[46] integrates data from the Connected Vehicle Pilot Deployment programme with other data sources, such as highway detector data, travel time data, traffic signal timing data, incident data, weather data and automated vehicle data. As a complement to this, the ITS JPO manages and provides the ITS CodeHub[47], which is an open source code management system for the ITS community to discover reusable software code, technical documents and configuration files.

Regarding air traffic management, the US and European systems are operated with similar technology and operational concepts, but the key difference is that the US system is operated by one single service provider (ANSP) using the same tools and equipment, communication processes and a common set of rules and procedures[48].

The Federal Aviation Administration (FAA), the agency responsible for airspace management and route design in the US, leads the NextGen programme with the aim of modernising the national airspace system (NAS). Since 2009, the FAA and the aviation community have been collaborating on the successful implementation of NextGen and in 2015 the programme was formalised by publishing a joint plan between FAA and the aviation community. NextGen will use satellite technology to enhance navigation and surveillance, deploy digital systems for communication and improve information management. The NextGen Priorities Joint Implementation Plan CY2019–2021[49] includes the four original focus areas: multiple runway operations (MRO), performance-based navigation (PBN), surface and data sharing, and data communications (Data Comm), and adds the Northeast corridor (NEC) as a fifth focus area in an effort to enhance operations in the most congested airspace in the NAS.

In 2011, the US and the EU signed a Memorandum of Cooperation (MoC) on civil aviation research and development. In December 2017, the MoC was amended to cover the full lifecycle of SESAR and NextGen programmes. The aim of the cooperation is to ensure the necessary harmonisation of the two programmes and to secure global interoperability to fulfil the principles of the ICAO Global Air Navigation Plan (GANP)[50].

In China, the explosive growth of its automotive market has led to unsustainable levels of congestion and pollution[51]. ITS solutions and improved NTM systems are key to address China's road infrastructure challenges. In this sense, the Draft Strategy for Innovation and Development of Intelligent Vehicles announced by the National Development and Reform Commission in 2018 states that, by 2020, wireless telecommunication networks for vehicles (LTE-V2X) will be available on 90 % of highways in big cities and, by 2025, a new generation wireless telecommunication network for vehicles (5G – V2X) will be operational[52].

The Ministry of Science and Technology in China also promotes the use of artificial intelligence in NTM systems. As one of the four national artificial intelligence open innovation platforms, Alibaba´s Cloud ET City Brain has been applied in the centre of Hangzhou to automate traffic signal control based on real-time data on traffic and accident detection[53].

In the domain of air traffic management, the Civil Aviation Administration of China (CAAC) developed the Civil Aviation ATM Modernization Strategy (CAAMS) in 2016 as part of CAAC´s thirteenth five-year development programme. CAAMS is also in line with the ICAO GANP and is expected to meet the future needs of increasing

[46] https://www.its.dot.gov/data/index.html
[47] https://its.dot.gov/code/
[48] Eurocontrol (2017), Comparison of air traffic management-related operational performance U.S./Europe, available at: https://www.eurocontrol.int/publication/useurope-comparison-air-traffic-management-related-operational-performance-2017
[49] https://www.faa.gov/nextgen/library/media/NACNextGenPrioritiesJointImplementationPlanCY2019-2021.pdf
[50] Coordination Committee (CCOM) & Deployment Coordination Committee (DCOM) (2018), NextGen – SESAR State of Harmonisation, available at: https://www.faa.gov/nextgen/media/NextGen-SESAR_State_of_Harmonisation.pdf
[51] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-china-will-help-fuel-the-revolution-in-autonomous-vehicles
[52] GIZ (2018), Defining the Future of Mobility: Intelligent and Connected Vehicles (ICVs) in China and Germany, available at: http://icv.sustainabletransport.org/
[53] https://www.alibabacloud.com/et/city

traffic flow and high-density airport operations in China. From 2016 to 2020, investment in building up China's modern air traffic management system will reach around 20 billion yuan (around EUR2.5 billion)[54].

China's high-speed rail network is now the most extensive in the world with around 27 000 km of high-speed lines in operation in 2018[55] with 577.6 billion passenger-km travelled in high-speed trains in 2017[56]. The Chinese Train Control Systems (CTCS) has Levels 0 to 4, which include, in Levels 1 – 4, the key attributes of the ERTMS solution while also adopting the advanced track circuit technology that is typical of the Chinese national rail network. The CTCS Level 3 is similar to the European ERTMS/ETCS Level 2 and is the leading ATP system on high speed lines. This is overlaid onto a CTCS Level 2 system, which is similar to ERTMS/ETCS Level 1, that provides the trackside infrastructure for units running 200 – 250 Km/h on dedicated passenger lines[57].

[54] International Civil Aviation Organization (2016), A39-WP/304: CHINA'S STRATEGY FOR MODERNIZING AIR TRAFFIC MANAGEMENT, available at: https://www.icao.int/Meetings/a39/Documents/WP/wp_304_en.pdf

[55] https://www.railjournal.com/passenger/high-speed/ten-years-27000km-china-celebrates-a-decade-of-high-speed/

[56] https://uic.org/IMG/pdf/20190122_high_speed_passenger_km.pdf

[57] UNIFE (2018), ERTMS Factsheet #23 The status of Railway Cab Signalling in China, available at: http://www.ertms.net/wp-content/uploads/2018/10/23-The-status-of-railway-CAB-signalling-in-China.pdf

5 Assessment of NTM 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[58].

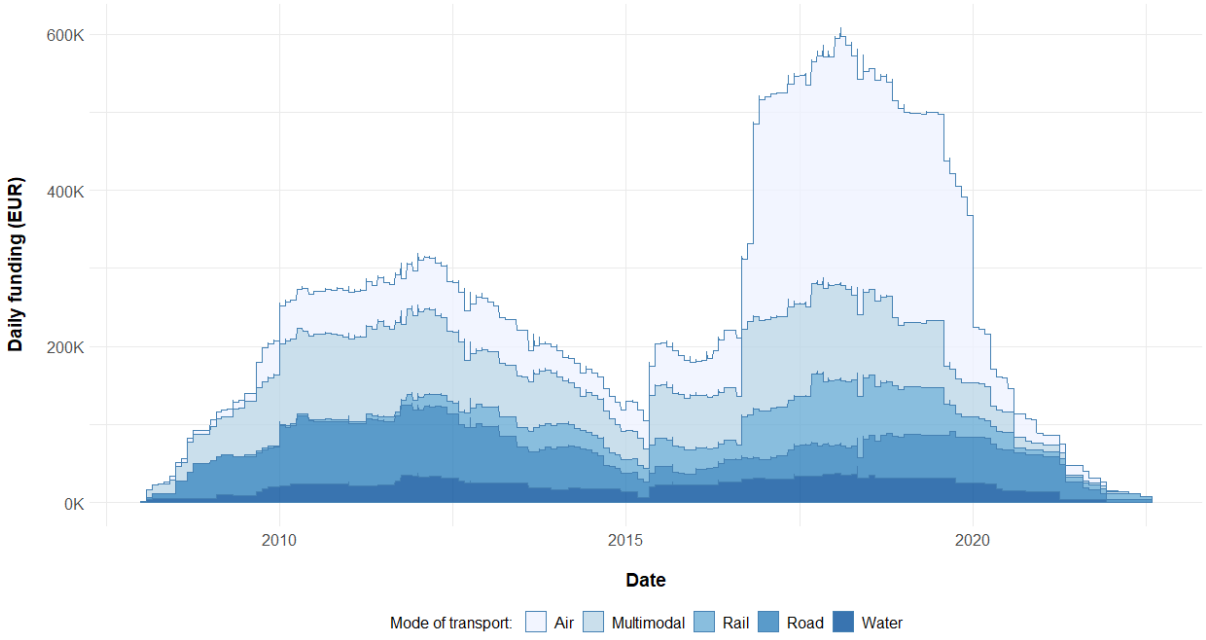
5.1 Framework programmes analysis

Under FP7 and H2020 about EUR 1.95 billion has been invested in NTM research projects. This includes EUR 1.3 billion of EU funds and about EUR 0.6 billion of own contributions by beneficiary organisations[59].

Figure 3 shows the aggregated funding trend since 2008, assuming that funds are spread equally through the project's duration. The figure shows that a large part of the funding is dedicated to air transport, which is explained by the many projects under the SESAR joint-undertaking (Single European Sky ATM Research)[60].

The daily funding culminated in the first quarter of 2019 above EUR 1 200 000. A funding forecast is also provided, which is based on those projects that were awarded by August 2019. As there are still upcoming H2020 calls, it is expected that the final funding will be higher.

Figure 3. Daily research funding by transport mode



Source: TRIMIS

5.2 Geographical and organisation analysis

A total of 2 335 unique organisations participated in FP7 and/or H2020 projects on NTM figure 4 shows the top 15 beneficiaries with the total amount of funds received and their research focus in terms of transport mode.

Most organisations focus exclusively on NTM research in one mode of transport, whereas some conduct research across modes. Of the top 15 beneficiaries, 15 are active in aviation, 4 in road, 5 in multimodal, 5 in

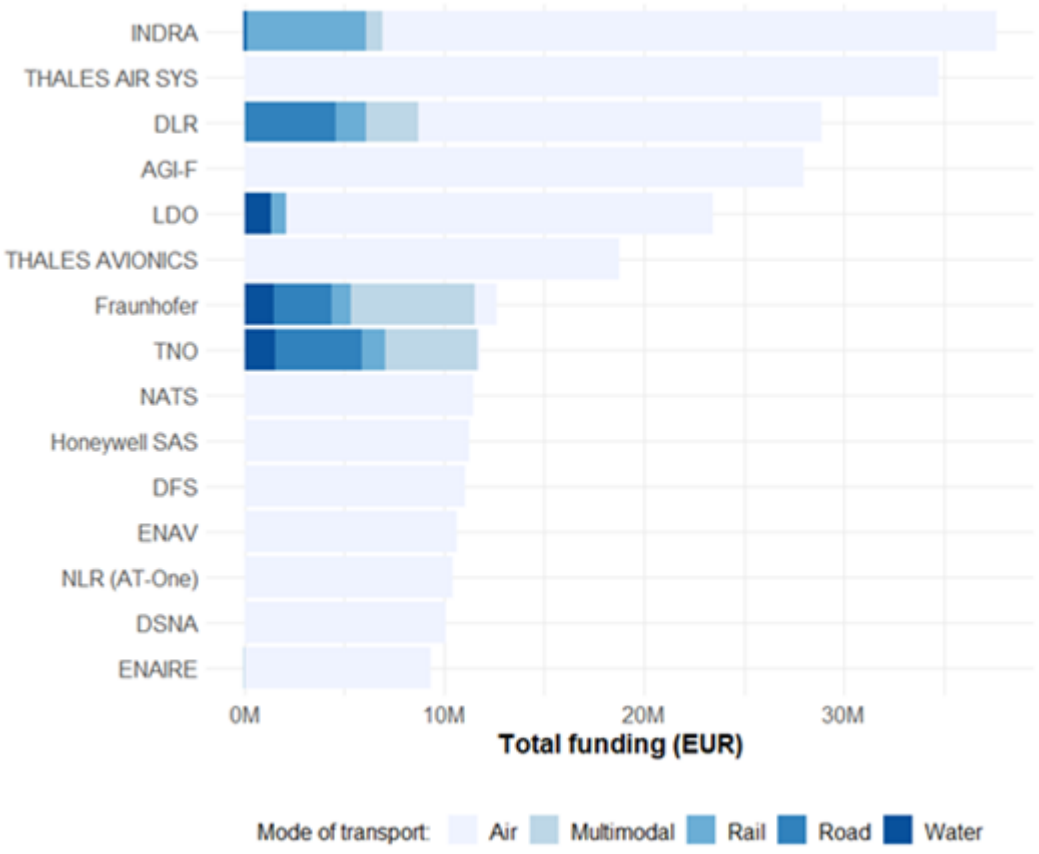
[58] https://www.gov.uk/government/publications/continued-uk-participation-in-eu-programmes/eu-funded-programmes-under-the-withdrawal-agreement

[59] As indicated in section 2, projects can research multiple topics. No distinction could however be made regarding the share of funding that is directed towards each specific topic. Consequently, the identified budgets should be understood as the upper limit of funding in this specific field.

[60] Disclaimer on SESAR's projects during FP7 timeframe

rail, and 4 in waterborne transport. The largest beneficiaries in the field of NTM are clearly active in aviation research.

Figure 4. Top 15 NTM funding beneficiaries



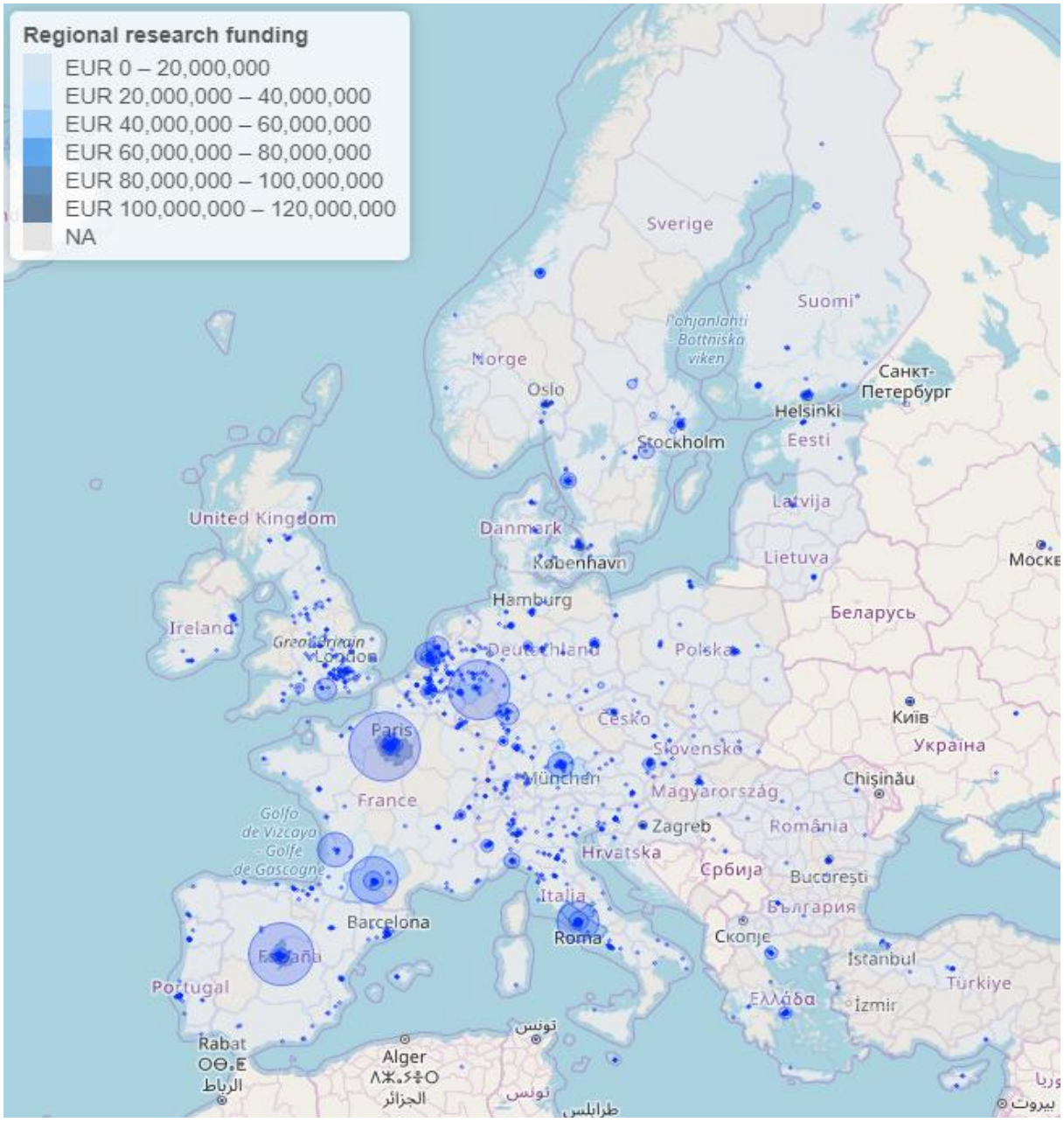
Source: TRIMIS

The top 15 beneficiaries received approximately EUR 270 million of funding, which is approximately 21 % of the total NTM funding budget. The funding concentration is therefore somewhat higher when compared to other roadmaps, where the figure floats between 11 % and 24 %.

Figure 5 provides a better look at the geographical spread of the funds. Several beneficiaries in France, Germany and Spain receive a large share of the funding, as indicated by the size of the circles. The main beneficiaries appear to be located in areas where plane manufacturers and aviation research organisation operate.

One footnote 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 NTM funding beneficiaries

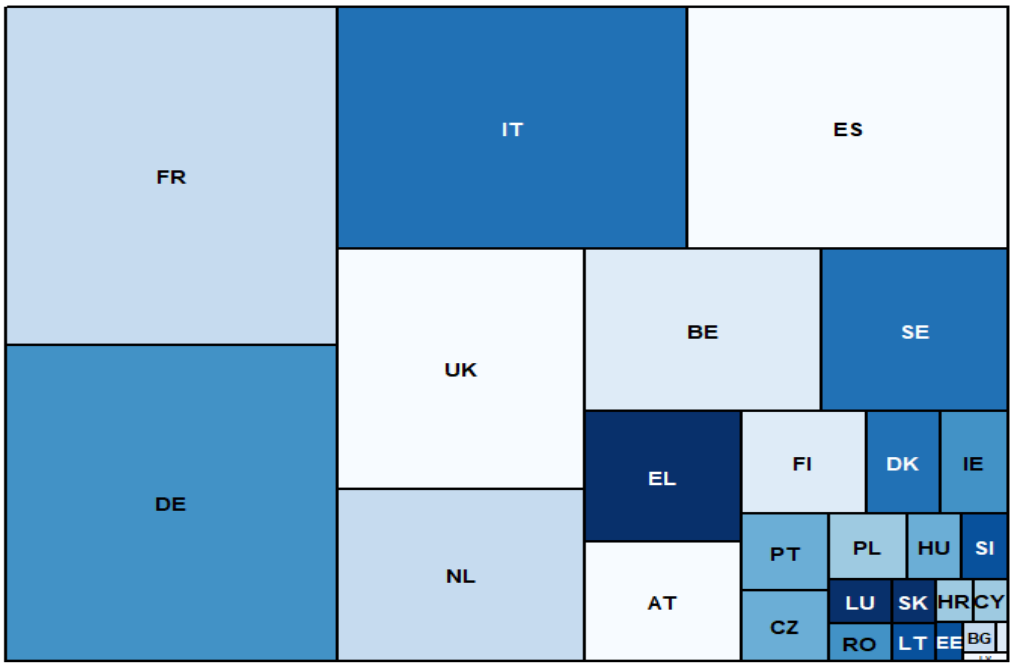


Source: TRIMIS

5.3 Country analysis

The assessment of FP7 and H2020 NTM research in terms of funds received by country, based on the beneficiaries' addresses, shows that France is the largest beneficiary in absolute terms, closely followed by Germany (Figure 6)

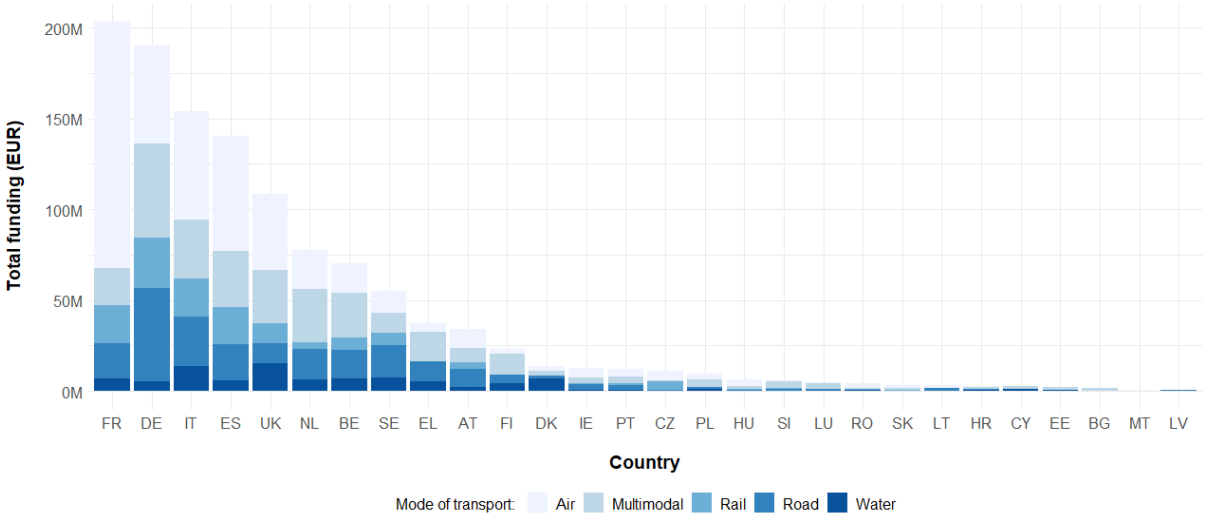
Figure 6. Shares of NTM funding by country



Source: TRIMIS

Figure 7 provides a more detailed overview on NTM research funding, showing the total amount of funding received per country split by mode of transport. The figure also highlights that there are several differences between countries when it comes to the mode of transport that is researched. For example, in France there seems to be a predominant focus on aviation research whereas German beneficiaries conduct research on NTM more evenly between the various modes.

Figure 7. NTM funding by country, split between transport modes



Source: TRIMIS

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

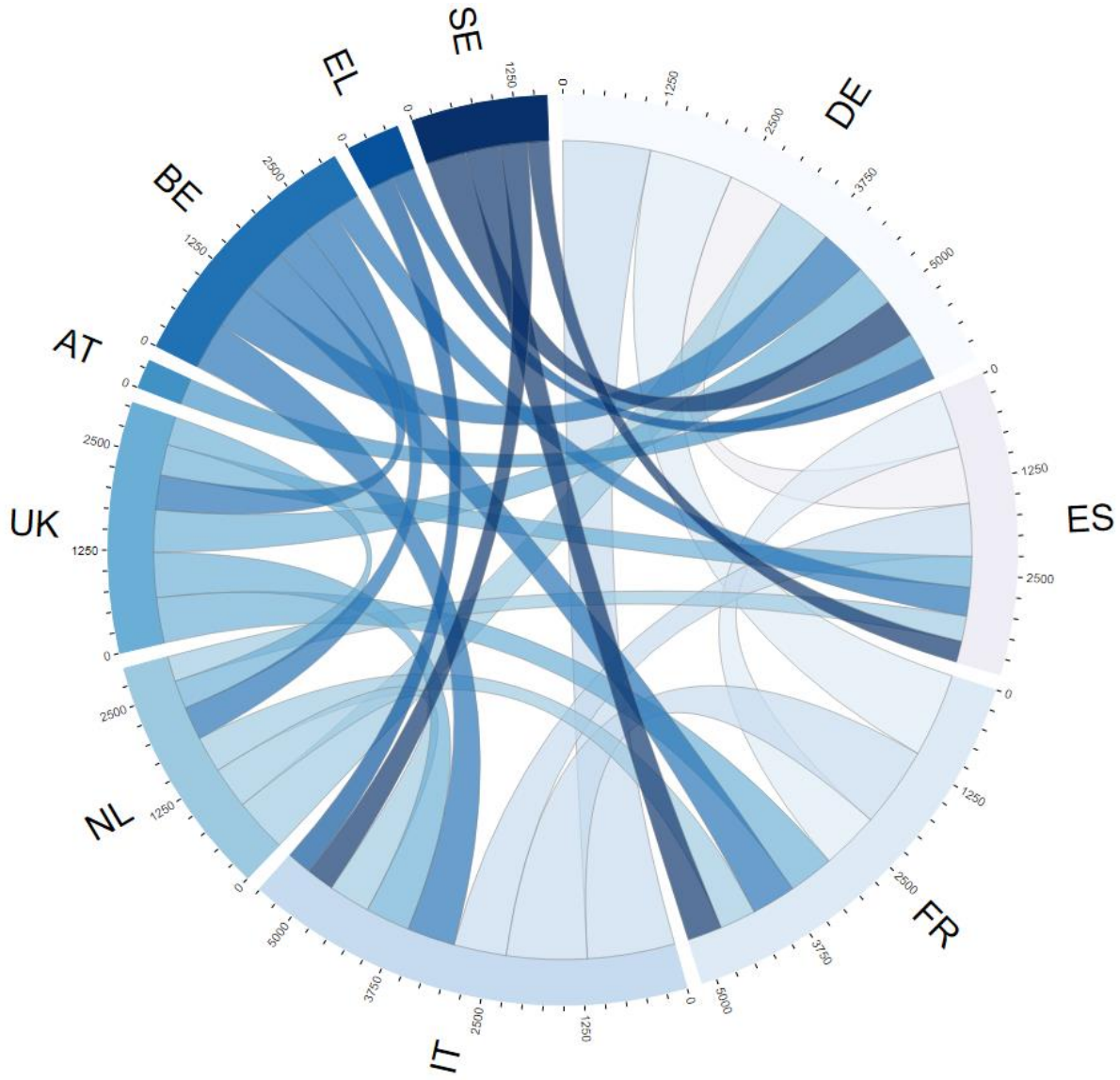
Figure 10 shows the most common links by highlighting those collaborations between organisations from European countries that occurred at least 250 times. This means for instance that if in a project one Spanish and two Austrian organisations collaborate, the link between Austria and Spain gains a strength 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.

Eleven 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 as was used in Figure 9.

A few observations can be shared. Unsurprisingly, the larger European countries are most visible in this chart. Additionally, Sweden, Greece and Austria are notably present. 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 NTM projects by country

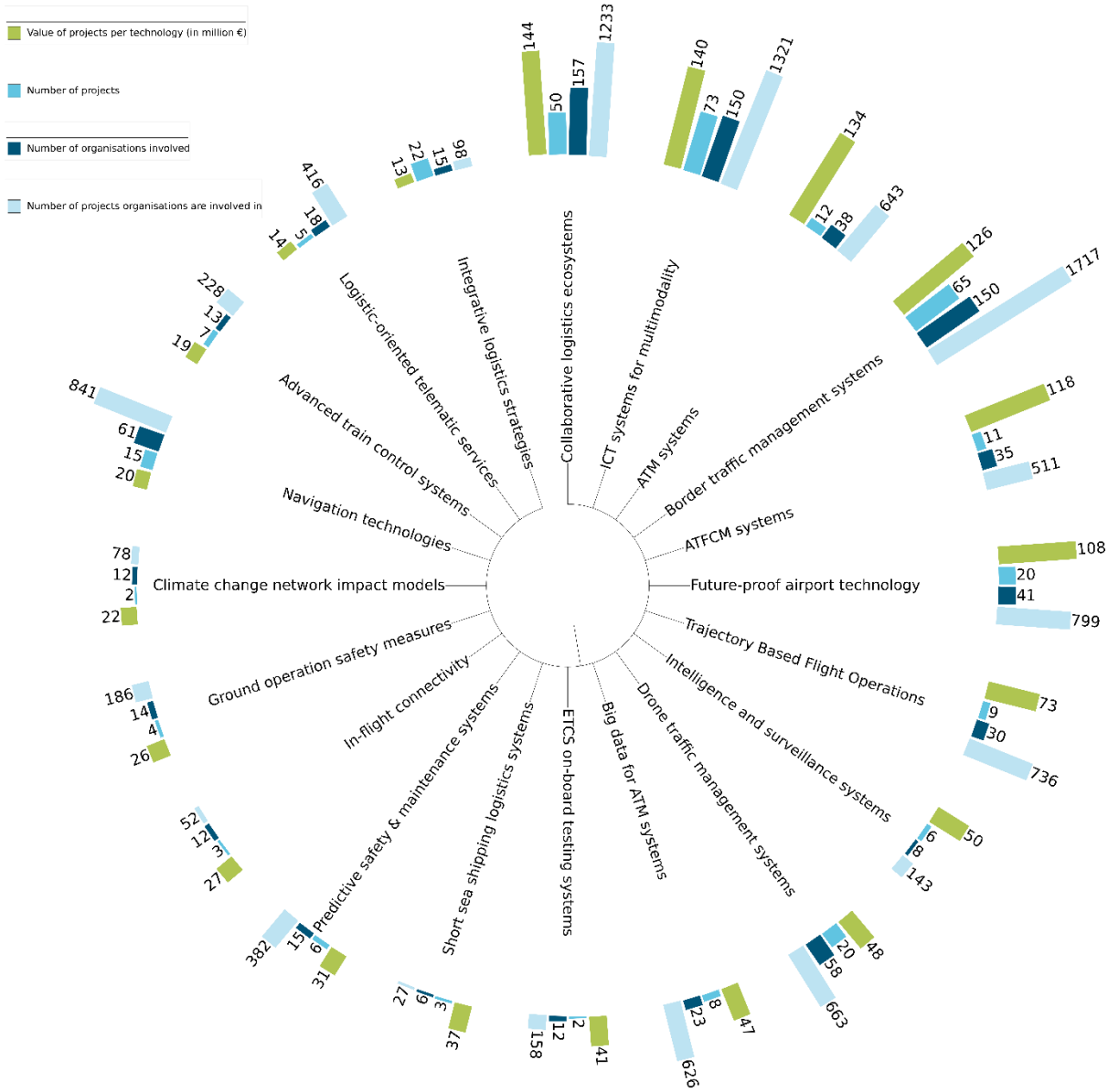


Source: TRIMIS

5.4 Technologies identified in the NTM roadmap

The analyses presented focus on the overall 'top 20' technologies identified for the NTM roadmap. The radial structure of Figure 9 highlights the key metrics of the 'top 20' technologies in terms of total funding.

Figure 9. Top 20 NTM technologies in FPs



Bars not in scale. Abbreviations: ATM – Air Traffic Management; ATFCM – Air Traffic Flow and Capacity Management; ETCS - European Train Control System.

Source: TRIMIS

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 this analysis are given below.

Among the top-20 technologies, 10 are linked to aviation, five to multimodal transport, three to waterborne transport, one to rail and one to road transport.

Six technologies received each a funding of above EUR 100 million: collaborative logistics ecosystems, ICT systems for multimodality, border traffic management systems (linked to multimodal transport), and, ATM systems, ATFCM systems and future-proof airport technology (linked to aviation). Among the technologies identified, ETCS on-board testing systems and climate change network impact models have been researched each only in two projects. The first, received most of the funding from the Shift2Rail project X2RAIL 3 (Advanced Signalling, Automation and Communication System – Prototyping the future by means of capacity increase, autonomy and flexible communication), while the second, from projects ACCESS and SEDNA, from FP7 and H2020 respectively.

Although the approach taken here has its limitations, the exercise of linking several technology metrics with organisational data can be useful for identifying technology value chains and 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 programme, developed by the US National Aeronautics and Space Administration (NASA) in the 1970s.

The EC advised that EU-funded R&I projects should adopt the TRL scale in 2010; TRLs were then implemented for the H2020 programme (Heder, 2017), although in practice TRLs are not assigned to all H2020 projects. TRLs are based on a scale from 1 to 9, with 9 being the most mature technology.

In TRIMIS, the nine TRLs have been consolidated into four development phases: basic 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.

Table 3 provides the description for each of the nine TRLs, as taken from Annex G of the H2020 work programme (2014-2015)[61] and the corresponding development phases used in TRIMIS.

[61] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

Table 3. Technology readiness levels (TRLs) and corresponding TRIMIS development phases

Scale	Description	TRIMIS development phase
TRL 1	Basic principles observed	Basic 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 (2014-2015) Annex G and TRIMIS

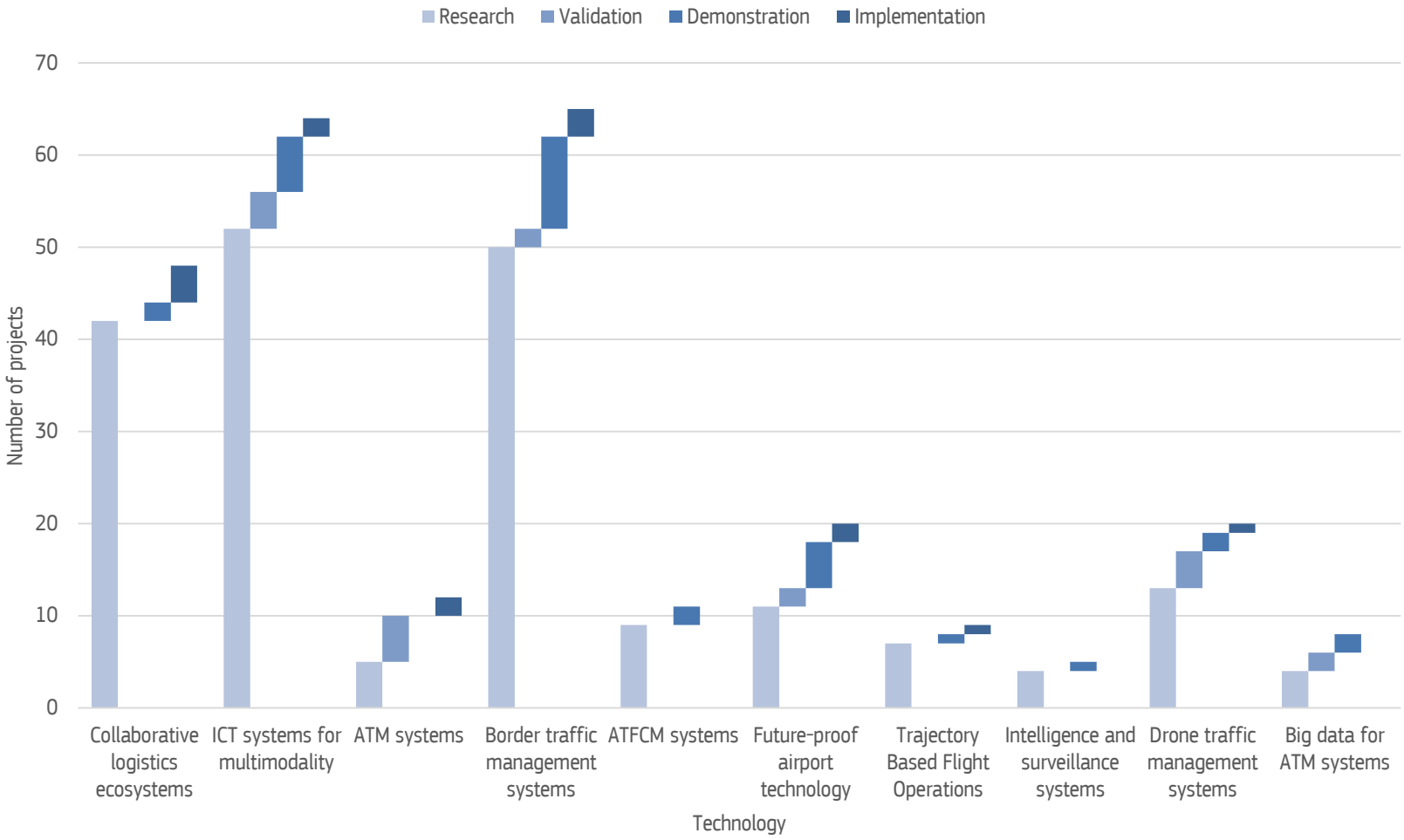
Figure 10 presents the development phases of the top ten researched NTM technologies in FPs.

Four of the top-10 technologies have been researched along the entire development phase spectrum, namely: ICT systems for multimodality, border traffic management systems, future-proof airport technology, and, drone traffic management systems.

Even though most NTM technologies have been researched in a large number of projects, some of them receive funding exclusively from few. *Drone traffic management system* have received most of their funding from the COMP4DRONES (Framework of key enabling technologies for safe and autonomous drones' applications) H2020 project. *Intelligence and surveillance systems* have received almost the entire funding (EUR 49 million) from the still ongoing PJ18 4DTM (4D Trajectory Management) H2020 project. Finally, *Trajectory Based Flight Operations* have been researched almost exclusively in SESAR JU projects.

The technology maturity analysis is ongoing and will be extended in the future to include additional projects (more notably CEF projects) something that will allow to have a broader overview of the implementation stage of more mature technologies.

Figure 10. Development phases of the Top 10 researched NTM technologies in FPs



Source: TRIMIS

5.5 Analysis on scientific research

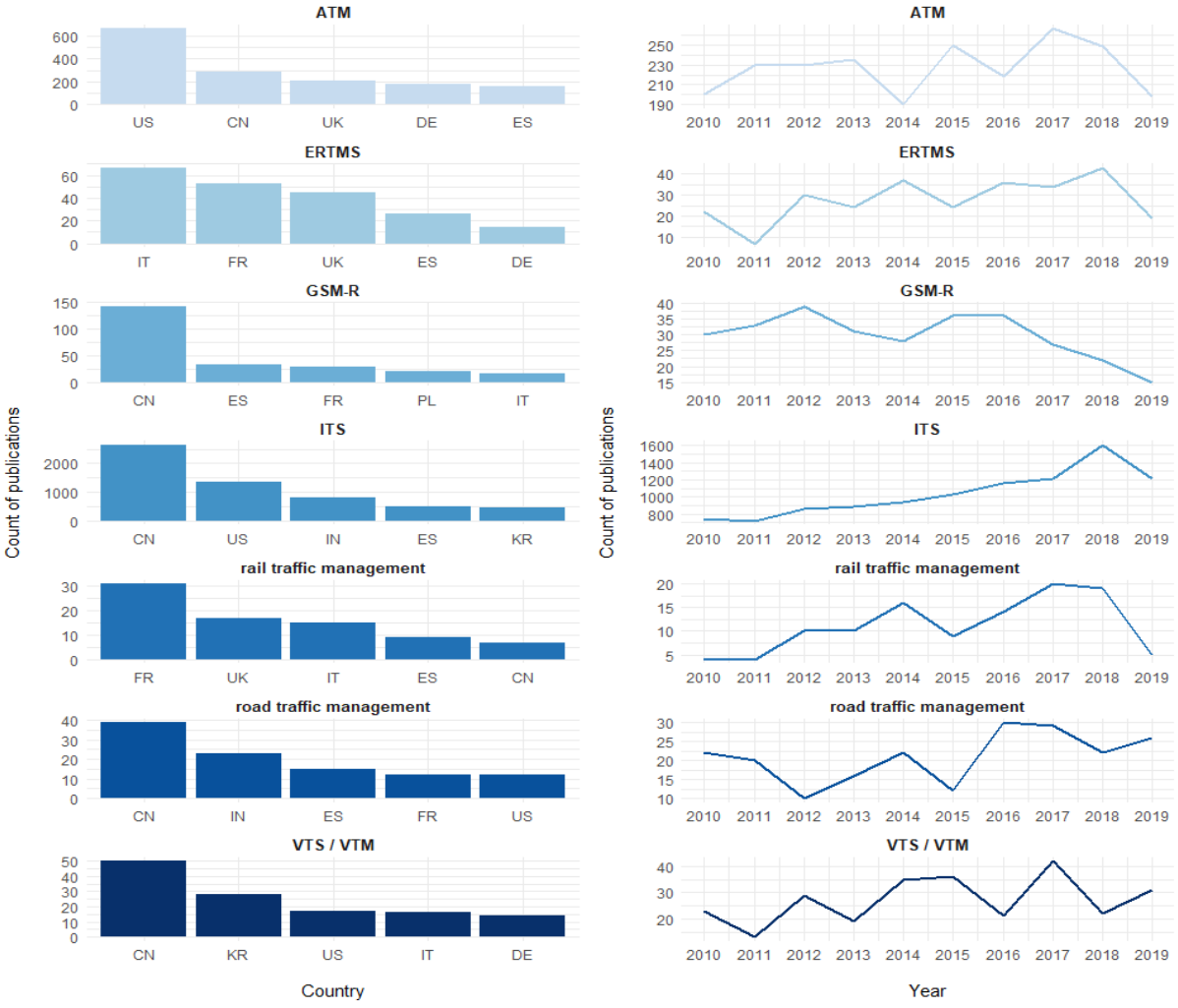
The following section discusses the evolution of international peer reviewed scientific publications on NTM since 2010. It allows us to compare the scientific output of Europe with other countries.

The analysis builds on the Scopus citation database for scientific research[62], looking for topics in the publications' title, abstract and keywords. The scope includes journal articles, book chapters and conference proceedings that are published between 2010 and 2019.

Considering the broadness of the topics addressed in the NTM roadmap, only topics that could be accurately and specifically linked to the roadmap were retained[63]. The topics are transport mode specific (air: ATM / rail: ERTMS, GSM-R or rail traffic management / road: ITS or road traffic management / water: Vessel Traffic Service (VTS) or Vessel Traffic Management (VTM)).

Figure 11 shows the results per topic, both in terms of geographical origin of the publication (in the bar charts on the left) and the publication trends throughout time (in the line charts at the right). Below several insights are highlighted.

Figure 11. Scopus analysis on NTM topics



Source: TRIMIS elaborations based on Scopus. Free scales.

[62] www.scopus.com

[63] The complete list of regular expression (REGEX) used is reported in ANNEX 2. The keywords were determined in function of their relevance and accuracy. Please note that only English keywords are used, which makes that publications in other languages are not accounted for.

In terms of geographic distribution and relative to other countries, we see that European researchers are most active in research on rail traffic management and ERTMS in particular. When it comes to GSM-R, the wireless communications standard for railways, Chinese authors have published significantly more. Likewise, VTS / VTM and ITS are topics that attract a relatively high amount of attention in China. The US seems to lead in number of publications on ATM.

Concerning the publication trends one can observe that the interest in all topics remained fairly stable over time, with the exception of ITS. Here, a big increase in publications takes place. One reason may be that ITS increasingly acts as a fashionable portmanteau for several NTM technologies and therefore covers an increasingly broad domain.

When comparing the research attention per mode of transport, waterborne transport receives least attention. While VTS / VTM should cover a large number of waterborne NTM publications, it is acknowledged that more research can be retrieved by expanding the number of keywords. It is nevertheless believed that the keyword search gives an insight into the relative research attention.

6 Research and Innovation assessment

This section analyses research and innovation projects in the field of NTM under six 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. Traffic management systems.

   This sub-theme focuses on projects which develop and implement traffic management systems. The sub-theme includes innovations in rail, road and waterborne traffic management, including collision avoidance systems and travel time optimisation systems. The sub-theme also covers advanced train control systems, transport demand and network models and systems providing analysis of visual and quantitative data to improve the flow of traffic.

2. Air traffic management.

   This sub-theme focuses on projects which develop and implement technologies to improve air traffic management (ATM). Due to the significant number of projects focusing on aviation as a transport mode, and the amount of funding directed towards aviation projects (largely linked to Single European Sky ATM Research (SESAR)), a separate sub-theme covers this transport mode. This includes ATM systems, trajectory-based flight operations and ground operation safety measures. In addition, drone traffic management systems also fall within this sub-theme.

3. Intermodal management systems.

   This sub-theme focuses on the development of intermodal management systems. This includes projects which deliver support systems for multimodality and communication networks for intelligent mobility. In addition, projects aiming to encourage the shift towards intermodal transport, through enhancing the passenger experience and easing modal shift, are also included in this sub-theme. The sub-theme also covers intermodal management of freight transport, where intermodality is the most significant aspect of the project.

4. Travel hub management.

   This sub-theme focuses on projects which develop systems for effective travel hub management. The sub-theme includes projects developing future-proof airports and ports, innovative solutions for seamless train stations and smart city technologies. In addition, projects developing parking management technologies are covered by this sub-theme, as parking management solutions enable transport users to shift mode from privately-owned vehicles to public transport or active travel modes.

5. Freight transport and logistics.

   This sub-theme focuses on projects which aim to enhance the efficiency of freight and logistics. This includes projects which deliver collaborative logistics ecosystems, logistics-oriented telematics and optimal cargo loading systems. In addition, the sub-theme covers vessel telematics and decision support tools, online container booking platforms and freight transport action plans.

6. Sensors and detection systems.

   This sub-theme focuses on the use of innovative sensors, radars and other detection systems to improve traffic management. This includes projects which focus on intelligence and surveillance systems, as well as communication technologies. In addition, this sub-theme covers satellite communication technologies that are used for guidance, navigation and safety purposes.

Each sub-theme involves projects which develop and deliver technologies relating to the optimisation of networks and the development of traffic management systems. Therefore, there are several interlinkages between the different sub-themes, despite their individual emphases on specific technologies or modes. In particular, there are strong links between traffic management systems and sensors and detection systems. However, due to the significant number of projects focusing specifically on the development of sensor and satellite technologies, these projects have been separated from broader traffic management system projects. It is important to note that the majority of the sub-themes cover multiple modes of transport, with the exception of air traffic management, which focuses on aviation and drone technologies. Air traffic management is separated from traffic management systems, due to the significant levels of funding allocated to aviation (largely linked to SESAR), and the high number of air traffic management projects falling

under NTM, which exceed the number of waterborne, road, rail and multimodal traffic management system projects combined. This is displayed in **Error! Reference source not found.**. It provides a summary of the umber of projects on NTM by three key funding instruments, the associated total project value and the EU funding contribution, split by the six sub-themes. Project selection was initially based on European-funded projects, with start dates from 2012 onwards, producing 330 projects. Two projects starting in 2011 were also included (i.e. EMAR and CONTAIN), due to their significance to traffic management systems in the maritime sector.

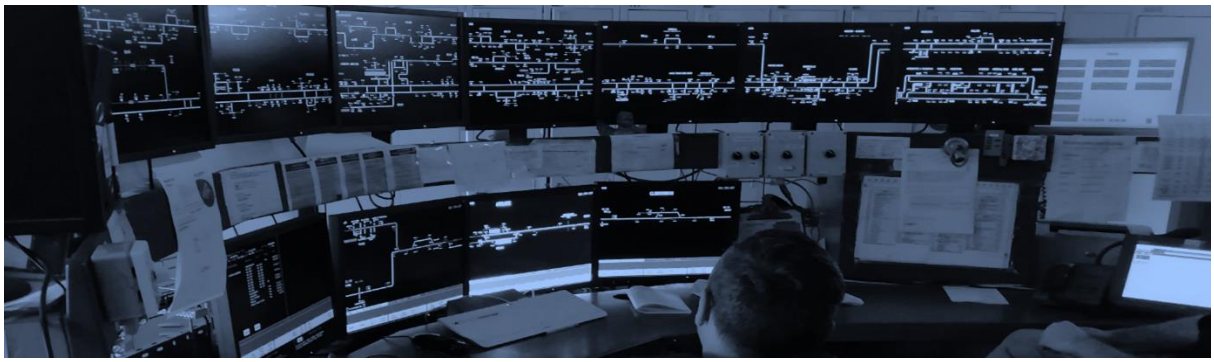
Table 4. NTM project summary table

Network and traffic management theme	Total project value (mEUR)	Total EU contribution (mEUR)	Number of projects			
			Total	FP7	H2020	CEF
Traffic management systems	235	145	58	11	40	7
Air traffic management	1 108	495	70	3	66	1
Intermodal management systems	50	34	20	6	14	-
Travel hub management	149	63	34	3	31	-
Freight transport and logistics	200	168	62	13	45	4
Sensors and detection systems	221	122	88	31	56	1

Source: TRIMIS

In the projects analysed in the rest of this section, reference will be made to TRLs and, in particular, the TRIMIS development phases of the projects in each sub-theme, as was shown in Table 3 in the previous section. This will provide an indication of the maturity of the technologies under each sub-theme, offering an insight into the implications for future research.

6.1 Sub-theme 1 – Traffic management systems



This sub-theme covers projects which develop and implement traffic management systems. It includes technologies which aim to enhance the safety and efficiency of transport by delivering systems which improve collision avoidance, navigation and travel time optimisation. Due to this, there are tangible overlaps between this sub-theme and the final sub-theme on sensors and detection systems. However, the projects covered by this sub-theme focus on the broader traffic management systems, rather than the specific sensor technologies.

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

- Travel time optimisation systems;
- Train control systems;

— Transport demand and network models;

— Systems providing analysis of visual and quantitative traffic data.

This sub-theme is important, as it captures projects which aim to deliver complete traffic management systems, across road, rail, waterborne and multimodal traffic. These projects aim to enhance safety and improve efficiencies in transport systems, through developing solutions which enable traffic to be better managed.

6.1.1 Overall direction of R&I

The design and implementation of traffic management systems has witnessed significant innovation over the past decade, across all modes and spatial scales. As cities aim to transform mobility systems into low-carbon networks, NTM systems are beginning to move beyond travel time optimisation to assist with achieving additional objectives, such as facilitating city-level reductions in air pollutant and greenhouse gas production.

The core focus of traffic management systems research varies depending on the mode. In regard to road transport, the primary technological developments include strategic network management, incident management and speed control. Developments in urban mobility technologies, to support the uptake of public transport, have also been a key feature of research. In addition, as cooperative intelligent transport systems (C-ITS) continue to emerge, automated driving technologies are displaying strong links with NTM research. This is blurring the edges between the NTM, cooperative, connected and automated transport (CAT) and smart mobility and services (SMO) STRIA roadmaps, whilst enhancing the efficiency and ease of NTM systems in a digitalised transport system.

In regard to rail transport, the European Rail Traffic Management System (ERTMS) has been a significant beneficiary of funding programmes. The primary focus has been on the development of communication systems as a foundation to facilitate interoperability in the rail sector. In addition, technologies exploring cyber security and safety in relation to rail transport are also beginning to emerge.

Research into waterborne transport is less extensive, as traffic management is primarily organised through internationally-recognised markings and through local pilots. Therefore, the absence of digital traffic management systems primarily concerns navigation in open seas. However, technologies are emerging to drive the development of traffic management across waterborne transport.

6.1.2 R&I activities

A total of 58 projects were assigned to this sub-theme, with the majority funded by Horizon 2020. To provide a more detailed analysis, some key projects were selected to demonstrate the core areas of research undertaken relating to the NTM 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.

— CONTAIN (2011-2015) is an FP7-funded project, which aimed to demonstrate a European shipping containers surveillance system. The project aimed to make regulatory, policy and standardisation recommendations, supporting transport security stakeholders to manage container security threats. CONTAIN aimed to undertake standardisation activities, to develop cost-effective solutions for shipping container security. The project aimed to demonstrate multimodal corridor design and chain monitoring control across international and European corridors at Interporto Bologna, Rotterdam, Amsterdam and Valencia.

— NGTC (2013-2016) is an FP7-funded project, which intended to deliver Next Generation Train Control (NGTC). The project aimed to analyse the required functionalities of mainline and urban train networks, as well as identifying the commonalities between the software and hardware platforms. NGTC did not aim to develop a 'one size fits all' system, but rather to drive progress for all railway domains through enhancing commonality in system design. In addition to enhancing commonalities between systems for urban and H2020 mainline rail systems, the project also aimed to apply new technologies to the train control system.

— EMAR (2012-2014) is an FP7-funded project, which planned to enhance safety and security in the maritime sector. The project aimed to enhance the automation of operations, particularly compliance management, and facilitate the streaming of synthesised information to assist decision-making. EMAR aimed to identify the implications for standardisation, develop measures to address legal and organisational inconsistencies and undertake cost-benefit analysis of new business models relying on e-

Maritime services. The project aimed to develop an e-maritime platform, which would offer comprehensive software infrastructure to support the implementation of the e-Maritime Strategic Framework, providing a repository for where e-Maritime Applications could be downloaded and a software development environment for producing e-Freight applications.

— EBSF_2 (2015-2018) is an H2020-funded project, which facilitated joint collaboration of industry experts, operators and authorities, to enable the testing and evaluation of a set of technological solutions for improved efficiency of urban and suburban bus systems. The project also aimed to improve the attractiveness of bus systems to users. The primary objective of the European Bus System of the Future 2 project was to validate different innovative solutions that combine efficiency of the bus system with enhanced user acceptance. The project aimed to develop solutions which would proceed from final validation to commercialisation, assisted by demonstrations across European 12 cities.

— MERLIN (2012-2015) is an FP7-funded project, which aimed to test the viability of an integrated management system, to achieve a more sustainable and optimised energy usage in mainline electric railway systems across Europe. MERLIN aimed to provide an integrated optimisation approach, supporting operational decisions, which lead to cost-effective intelligent energy management systems. The project aimed to engender an improved understanding of the influence of energy demand on railway system operations and operational procedures. The project also aimed to deliver the interface protocol and architecture for energy management systems in the railway domain, combining technical development and new business models to facilitate their application.

— SCOOP@F Part 2 (2016-2019) is a CEF-funded project, which sought to deliver a largescale C-ITS pilot, connecting 3 000 vehicles with 2 000 km of roads. The project aimed to enhance the road safety of users, as well as improving traffic management. The project aimed to test the deployment of C-ITS, through developing an efficient security system to ensure the privacy of users and through preparing key industry and government stakeholders for initial deployment. The project also aimed to develop a hybrid communication system and to contribute towards the interoperability of C-ITS across the EU.

6.1.3 Achievements

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

— CONTAIN established corridor container maps to enhance surveillance, as well as outlining secure trade lanes between the EU and its trading partners. The project also developed tools and methods for increasing container transportation security, through a unified information distribution system. The project developed a comprehensive toolkit and platform, which included both equipment and risk analysis software. The system was implemented in three European ports to validate the technologies, manage empty containers and expand supply chain security. CONTAIN provided improved positioning technologies, developing state-of-the-art container security equipment. The project developed the means for locating containers, which have been declared empty, helping to streamline container traffic and enhance competitiveness in the sector, bringing the container security equipment technologies developed from an initial basic research phase to validation.

— NGTC analysed the required functionalities of two major train control systems, the European Train Control System (ETCS) and communications-based train control (CBTC) systems. The project examined the similarities in the architecture, hardware platforms and design of the two systems. The proposed solutions are based on the experience of ETCS, and its standardised train protection kernel. The solutions also draw upon the experiences which suppliers have gained by having developed sophisticated CBTC systems internationally. As stated, the project did not intend to develop a 'one size fits all' system, but to engender progress in the commonality of system design across railway domains, to enable suppliers to benefit from economies of scale and to enable customers to choose the most competitive supplier, based on standardised functions and interfaces. NGTC also undertook an in-depth study on the future generations of IP-based radio communications, and significantly progressed the research into satellite-based train positioning suitable for ETCS.

— EMAR developed a new software application, designed to make reporting obligations for shipping operators simpler and more cost effective. The new system, i-Ship, connects vessels, operators and reporting authorities together in a collaborative web-based reporting system that offers greater clarity and speed. The system achieves this by providing a single link for shipping companies to submit their reporting formalities. The system, i-Ship, is fully compliant with EU administrative procedural laws, and

also offers users a range of advanced reporting features, including pre-loading and notifications. Other benefits include complete system integration and customisation, along with visibility of the reporting and compliance status of any given fleet. This application is one example of how EMAR assisted in making European maritime transport more secure and more competitive, bringing the web-based reporting system developed under the project from basic research to demonstration and implementation. EMAR is also closely aligned with the objectives of the TEN-T programme, which aims to develop an efficient trans-European transport network.

— EBSF_2 demonstrated the technological solutions developed under the project, for improved efficiency of urban and suburban bus systems, in 12 cities (Barcelona, Dresden, Gothenburg, Helsinki, London, Lyon, Madrid, Paris Area, Paris City, Ravenna, San Sebastian, and Stuttgart). The demonstrations addressed several key areas of innovation, including intelligent garage and predictive maintenance, the interface between the bus and urban infrastructures, and the introduction of IT standards for existing fleets. The technological innovations to be tested within the demonstrations include a wide range of bus systems, from bus rapid transit (BRT) to local lines, as well as all current propulsion technologies. They have been identified according to their technological maturity, to facilitate efficient commercialisation after the project has been completed. Following the system approach, and with the participation of all key stakeholder categories, these activities will be introduced through the identification of innovation requirements and the update of the Bus System Definition. Through multiple demonstrations of the aforementioned technologies, the project effectively brought the interface between the bus and urban infrastructures, the introduction of IT standards and predictive maintenance technologies researched under the project from the validation to the demonstration development phase.

— MERLIN characterised the main railway networks in Europe by defining infrastructures, subsystems and components. Researchers then developed a graphical depiction of overall energy flow. The project articulated energy consumption maps for the railway power supply systems of networks in Spain, France, Sweden and the United Kingdom. Five case studies in four European countries helped to evaluate various aspects of improved energy management. The high-speed network from Paris to Lyon was included, to evaluate the introduction of an energy storage system (ESS) in order to improve line capacity. Scientists evaluated the standardisation and calibration of energy meters and information exchange protocols between components from on-board energy meters to smart grid components. MERLIN developed the components and management tools necessary for efficient energy resource management on European electric railways. The standardisation has made an important contribution to development, implementation and effectiveness, with optimised energy management for reduced consumption also being passed onto consumers in the form of reduced fares.

— Although SCOOP@F Part 2 is ongoing, the project is coming to a close. To date, the project has successfully built upon SCOOP@F Part 1, to finalise the validations of the system developed under this project. The project has also undertaken a series of pilot tests with EU Member States, to determine the real-world capabilities of the system. The project aims to introduce additional services, including multimodal capabilities, as well as to develop a hybrid communication system. When the project reaches its final conclusions, it will be important to examine its complete impact on road safety and traffic management systems.

6.1.4 Implications for future research

This sub-theme covers a large number of projects with a specific focus on traffic management and the development of technologies, which enhance the safety and efficiency of traffic across all transport modes, except for aviation which is covered in the next section. The majority of projects are at the early basic research stage of development, with several also at the demonstration and implementation phases. Funding for the projects under this sub-theme has been provided by SME-1 (for several, relatively small, projects) and RIA, reflecting the early stages of development of the majority of projects at inception, as well as other actions that have supported taking the technologies through towards demonstration and implementation.

The research undertaken under the broader theme of traffic management systems is diverse and covers multiple modes. Several projects, such as NGTC, cover traffic optimisation, and aim to establish commonalities across existing systems. The next step in research would see these projects move from initial development phases to implementation, to enable comprehensive control systems to benefit rail management. MERLIN also displays attempts to test train management systems, yet focuses on achieving improvements in energy usage. With sustainability underpinning the basis of several projects, it is important

that future research continues to develop traffic optimisation (as a means of reducing greenhouse gas emissions) and energy management systems.

Safety is a key foundation for several projects under this sub-theme. For example, CONTAIN, which also falls under the sub-theme on freight transport and logistics, aims to enhance security and safety in container management. As safety remains a key theme for EU-funded projects, as well as a key objective for EU-level policy, it is important that future research continues to develop innovative solutions to improving the safety of transport networks across all modes.

Traffic management systems which focus on urban environments are another key thematic area. Projects, such as EBSF_2, have displayed a focus on improving efficiencies in the operation of public transport, through improving digital infrastructure and interfaces deployed to enhance the efficiency of bus fleets. Tying safety and sustainability together, projects which focus on improving traffic management in urban areas should continue to focus on improving the digital infrastructure underpinning traffic management systems for public transport systems.

The majority of traffic management system projects relate to road transport, with several of these projects relating to developments and demonstrations of connected and automated vehicles, in addition to public transport and urban mobility management systems. There is a relatively even split between basic research, demonstration, validation and implementation development phases for road transport projects across connected vehicle and smart mobility projects, suggesting that furthering the research into all of these areas is necessary. Therefore, RIA, IA and CSA funding actions would all be relevant in the case of road transport.

In regard to rail transport, projects have primarily focused on the development of communication systems, to enable interoperability. As research into cyber security and safety continues to emerge, it will be essential to provide greater funding for the development and validation of these technologies. For waterborne transport, research into traffic management systems is in the earlier stages. Therefore, funding the initial research and development of technologies would be beneficial to help drive innovation, under SME-1 and RIA.

SCOOP@F Part 2 has contributed to the demonstration of technologies and vehicles, to highlight the capabilities of connected and automated vehicles to provide efficient and safe systems, as well as displaying the gaps remaining to encourage further development and uptake of these vehicles. Therefore, further research into the barriers for connected vehicle implementation could provide crucial insights to facilitate advancements in connected and automated vehicle uptake. It is likely that this research is captured under the CAT STRIA roadmap, which has a greater focus on the technologies being developed for connected and automated vehicles.

6.1.5 Implications for future policy development

The research undertaken in this sub-theme has largely focused on developing traffic management systems which aim to improve the efficiency, safety and sustainability of transport across multiple modes. A number of projects have moved from the initial basic research and validation phases to demonstration within the scope of the project, such as EBSF_2.

Although the majority of projects under this sub-theme are funded by H2020 and FP7, CEF is the key funding instrument implementing TEN-T policy in Europe. This includes ITS for road and ERTMS for railways, which relate to connectivity and traffic management in road and rail transport, respectively. The next CEF programme (2021-2027) is expected to focus on making transport more connected, sustainable, inclusive, safe and secure, which aligns with the current themes of the projects explored. Therefore, as the CEF programme develops, it is expected that funding for demonstration and largescale testing projects will support innovation across the key thematic areas of safety, sustainability and traffic optimisation, building upon NGTC and CONTAIN.

Given the early stage of market development for many of the technologies, it is important that innovation in traffic management systems is not restricted by policy measures which may limit the capacity for technological developments to take place. The legal framework for the deployment of ITS and advanced NTM systems in the road sector is provided by the ITS Directive (Directive 2010/40/EU). The Directive aims to ensure the compatibility, interoperability and continuity of ITS solutions across the EU, which supports the accessibility of EU-wide travel information for ITS users. Therefore, policy surrounding cooperation and collaboration between Member States is in place to help to ensure demonstration, and early stage implementation, of technologies and solutions across Member States in an interoperable fashion.

6.2 Sub-theme 2 – Air traffic management

This sub-theme covers projects which develop and implement air traffic management. Within this sub-theme, projects which aim to cover ATM systems, trajectory-based flight operations and ground operation safety measures are included. Therefore, the sub-theme also covers projects aiming to foster improvements in safety, navigation and efficiency in air travel. Key technology themes under this sub-theme include, but are not limited to:

- Airspace user support for network management;
- Design principles for improving safety and resilience in ATM;
- Environmentally-conscious ATM systems;
- Drone traffic management systems.

This sub-theme is important as it covers the significant number of projects funded by SESAR, which contribute to improving and bringing together the research relating to aviation across Europe.

6.2.1 Overall direction of R&I

ATM systems, which aim to combine airborne and ground-based functions, to enhance the safety and efficiency of air traffic operations, are a key area of research under NTM. The SESAR funding programme represents the backbone of the Single European Sky initiative, aiming to modernise ATM across Europe. In recent years, SESAR and complementary funding programmes, have aimed to enhance the interoperable and automated nature of air traffic, building upon the broader backdrop of technological innovation and the digitalisation of the transport sector.

Since 2008, SESAR has researched over 60 solutions, which are being implemented in response to local needs or through the EU's Pilot Common Project (PCP). The PCP aims to bring capacity benefits through encouraging reductions in flight delays, reductions in the environmental impact of aviation and greater operational efficiencies, through reducing flight times. Other than PCP, the focus of ATM technologies mirrors the aforementioned areas of operational efficiencies and passenger experience, and environmental impact. In addition, safety and navigation are still of paramount importance to ATM research.

6.2.2 R&I activities

A total of 70 projects were assigned to this sub-theme, with the majority funded by Horizon 2020. To provide a more detailed analysis, some key projects were selected to demonstrate the core areas of research undertaken relating to the NTM 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.

- PROSPERO (2012-2015) is an FP7-funded project, which aimed to develop an air traffic management system, bringing current air traffic systems up-to-date in regard to risk understanding and management. At the point of project implementation, there was minimal collaboration between stakeholders and an absence of an integrated risk metric. In addition, the anticipation of emergencies did not fall under the everyday modelled operations planning. PROSPERO aimed to deliver a common operational concept of performance indicators, linked to operational goals, a methodology for operational system analysis, a taxonomy for encompassing aviation system concepts and a risk management process.

— PJ10 PROSA (2016-2019) is an H2020-funded project, which seeks to provide air traffic controllers with more automated tools, thereby allowing them to concentrate on situations where human intervention is crucial. The project aims to not only improve current conflict detection tools, but also develop new tools supporting the air traffic controller with resolution advisory and monitoring of flight trajectory. The project will address new ways of working together, taking into account new developments, such as drones. The project is funded by SESAR and aims to develop new tools for improving air traffic control, through resolution advisory and monitoring of flight trajectories.

— RESILIENCE2050.EU (2012-2015) is an FP7-funded project, which intended to develop new principles for fostering safety, agility and resilience for air traffic management. The project aimed to analyse current system behaviour, focusing on the preparation for undesired events and building the future ATM concept designed to adapt to disruptions. In addition, the project aimed to provide a methodology to address resilience in the system. The project analysed current system behaviour, focusing on the propagation of undesired events. The project also aimed to develop a future-fit ATM concept, designed to adapt to disruptions and perturbations, and provide a methodology to address the resilience of the system.

— Future Sky Safety (2015-2019) is an H2020-funded project, which aimed to achieve the highest levels of safety to ensure that passengers and freight, as well as the air transport system and its infrastructure, are protected. Trends in safety performance over the last decade indicate that the Advisory Council for Aeronautics Research in Europe (ACARE) Vision 2020 safety goal of an 80 % reduction in the accident rate is not being achieved. Therefore, the project aimed to highlight that a stronger focus on safety would be required, suggesting the need to start a Joint Research Programme (JRP) on Aviation Safety.

— Airline Team NCM (2018-2020) is an H2020-funded project, which plans to develop the 'future ATM system'. ATM is perceived as a critical attribute in the broader air transport value chain, key to connecting Europe's regions, as well as establishing a global hub for connectivity. This project builds upon trajectory-based operations, relying on the provision of air navigation services in support of the execution of the business or mission trajectory. This is facilitated by an increase in the level of automation across the sector, the implementation of virtualisation technologies and the use of standardised and interoperable systems.

6.2.3 Achievements

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

— PROSPERO developed and evaluated a prototype management system for analysing and managing complex aviation risks. Initially, the project commenced by defining industry requirements for the system, as well as key functional requirements and specifications for its design and preparation. To support the actual development and implementation of the system at different application levels, project partners carried out several case studies. The PROSPERO solution was successfully demonstrated in European airports, assessing air transport system risk, based on shared data between airports and airlines. The demonstrations supported compliance with, and fulfilment of, European regulatory requirements. Overall, findings showed that collaboration and data-sharing between a broad range of aviation stakeholders is challenging yet achievable. Even if the data available between various organisations is minimal, there are measurable gains for risk assessment and monitoring. The delivery of an effective prototype system for identifying and managing risks in the air transport system enabled the project to move from the basic research development phase to implementation.

— PJ10 PROSA is developing a concept of flight-centric air traffic control, and has refined and validated the concept at a series of workshops, with real-time simulations to increase controller productivity. The first set of exercises showed, as a continuity of SESAR 1, the benefits of tactical, planner and monitoring tools in different environments. It also showed the relationship between the level of accuracy of the trajectory and the efficiency of conflict detection and resolution tools. From the start of the project, three dedicated enablers, operational requirements and new operating methods, specific to Remotely Piloted Aircraft Systems (RPAS) integration, were developed and validated through real-time simulations. To date, this has enabled the air traffic control system developed under the project to move from basic research to validation and demonstration.

— RESILIENCE2050.EU aimed to achieve a deeper knowledge of the resilience concept in ATM, which was largely non-existent in ATM before 2011, only incorporating safety management aspects. At its inception, the project consolidated a theoretical ATM-Resilience framework agreed upon by aviation stakeholders,

both internal and external to the project. Thereafter, the consortium used the latest innovative data science techniques to mine different datasets to extract information to analyse the resilience of the ATM system to the different disturbances. Design principles were then derived by taking into account the quantitative assessments made through the data mining process, the operational knowledge of the consortium, and the necessary balance with other properties, such as agility and efficiency of the ATM system.

— Future Sky Safety (FSS) is still ongoing, yet important results have already been achieved. As a result of coordination between key stakeholders, a wide range of new, cooperative safety projects has materialised. For example, a dedicated project on runway excursions developed algorithms and monitoring techniques for reducing the risk of runway veer-offs. Following three successful flight tests, these tools can be used by both airlines and flight data monitoring software developers. Drawing upon a pan-European safety culture survey of 7 239 pilots and their perceptions of the safety culture in European aviation, FSS developed guidance on advancing the safety management of organisations, which was adopted by the European Union Aviation Safety Agency (EASA). Another important result is the development of the Human Performance Envelope (HPE), a new concept for cockpit operations and design. Through flight simulations, researchers have shown how the HPE approach can contribute to safeguarding human performance in flight upset conditions. Therefore, within the scope of the project to date, technologies, such as the HPE, have moved from basic research to demonstration.

— Airline Team NCM is developing demonstrations, which aim to improve coordination between partners to facilitate agreement amongst all relevant operational actors on the improvements needed to improve flow and flight measures. The tasks focus on bilateral coordination improvements and improvements in connecting with the network. All of the tasks will contribute to faster, more efficient communication, information sharing and cooperation between stake-holders, resulting in greater predictability, higher efficiency and fewer delays. More structured coordination using support tools will allow for more dynamicity and the fine-tuning of proposed measures, compared to traditional coordination means, such as telephone and email coordination. In addition, it will allow for much better control of situations where deviations to the original plan are required, such as weather disturbances.

6.2.4 Implications for future research

This sub-theme covers a large number of projects with a specific focus on air traffic management and the development of technologies which enhance the safety and efficiency of air traffic. The majority of projects are at the early basic research stage, with several also at the validation phase. Therefore, the vast majority of projects which fall under this sub-theme explore new technologies for advancing ATM, with few projects focusing on the implementation of existing concepts. The majority of projects are currently funded under the RIA action.

Several projects focus on improving risk management and safety, such as PROSPERO and Future Sky Safety. Some of these projects, such as Future Sky Safety, include demonstrations of technologies developing during the project, to test the capacity of new systems to accurately and effectively improve safety across the span of air traffic operations. Therefore, bringing these technologies to fruition, upon successful demonstration through the CSA and IA actions, will provide an impactful contribution to aviation safety.

Another key theme in research relating to ATM is automation. Both PJ10 PROSA and Airline Team NCM focus on bringing greater levels of automation to air traffic control, in attempts to minimise the level of human intervention required and enable more focused intervention where automation cannot fulfil the role of human decision-making. Projects researching this area of ATM range from basic research phase to implementation phase. Therefore, in cases relating to virtualisation technologies and more technologically-advanced systems, greater research could help to bolster the field.

6.2.5 Implications for future policy development

The research undertaken in this sub-theme has largely focused on ATM systems, with a number of projects moving from the initial basic research phases to demonstration within the scope of the project, such as Future Sky Safety. In regard to policy, the Single European Sky (SES) is the key initiative in the EU for improving air traffic safety, the sustainability of air transport and the performance of air navigation and ATM systems more broadly. The aims of the SES, to improve safety of air traffic by a factor of 10 and reduce the environmental impact of each flight by 10 %, align with the overarching themes addressed by the projects which fall under this sub-theme.

The SESAR programme, which is the key technological component of SES, has funded several projects under the sub-theme, and supports continuous development in air traffic safety, sustainability and efficiency. Given the early stage of development for many of the technologies, such as the ATM technologies researched under RESILIENCE2050.EU and PROSPERO, innovation in air traffic management should be encouraged by policy measures. The SES supports further research and development in relevant fields of ATM, and therefore, no immediate policy developments are necessary in relation to ATM. However, there is potential for the outputs of projects to have a greater impact on policy development. In addition, there is potential for policy to be adopted more widely. For example, the guidance on advancing safety management, which was produced by FSS, and adopted by EASA, could be implemented more broadly.

COM(2014) 207 sets a European strategy for the development of a common market of drone services, outlining the opening up of the aviation market to the use of remotely piloted aircraft systems. The Implementing Act, regulating the operation of unmanned aircraft systems (UASs), reduces the fragmented nature of current safety rules regarding drones. This will provide greater clarity for future research. Current projects focusing on drones, such as DAPS and SAFEDRONE, have undertaken widespread research into the network infrastructure requirements and safety aspects relating to drone operations. Recently adopted Regulation (EU) 2019/947 outlines the rules and procedures for the operation of unmanned aircraft, providing a clear framework for drone operations across the EU. It will be important to draw upon the findings of future research to ensure that the Regulation remains up-to-date with technological innovations.

6.3 Sub-theme 3 – Intermodal management systems

This sub-theme covers projects developing intermodal management systems. Therefore, the sub-theme includes projects which aim to develop support systems for multimodality and communication networks for intelligent mobility. Key technology themes under this sub-theme include, but are not limited to:

- Technologies enhancing user experience;
- Platforms for location services;
- Intermodal container freight systems;
- Cross-modal digital transport ecosystems.

This sub-theme is important as it aims to develop technologies which enhance the ease of multimodal travel, improving user acceptance and encouraging greater use of low-carbon transport modes.

6.3.1 Overall direction of R&I

As a shift away from vehicle-based traffic management systems occurs, technologies exploring multi-modal network management are becoming more intrinsic to the development of NTM research and innovation. Such an integrated approach requires the interoperability of the different technologies but also the integration of different business models and collaboration between infrastructure managers, the main transport operators and other stakeholders. The need to encourage the development of more sustainable transport systems, and direct transport users away from the use of privately-owned vehicles, has also provided the foundation for multiple research projects aiming to enhance multimodality.

In regard to intermodal management systems, several research projects are focused on facilitating multimodality in urban areas through traffic management tools. In addition, a number of projects fall under the Shift2Rail programme, aiming to engender a movement towards rail as a mode of transport. The majority

of projects are in the basic research development phase. However, a number of projects have delivered demonstrations over the lifetime of their project, which suggests that the TRLs of select projects would have progressed following the completion of the project. Due to the role of travel hubs as sites for altering transport mode, there are some linkages between the two sub-themes.

6.3.2 R&I activities

A total of 20 projects were assigned to this sub-theme. To provide a more detailed analysis, some key projects were selected to demonstrate the core areas of research undertaken relating to the NTM 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.

- TIMON (2015-2018) is an H2020-funded project, which aimed to develop real-time services for optimised multimodal mobility. The key objective of the project was to improve the safety, sustainability and efficiency of road transport systems, by processing open transport data. The project aimed to develop a cooperative open web-based platform and mobile application, with the purpose of delivering information to drivers, businesses and vulnerable road users (VRUs). TIMON aimed to empower drivers to deliver data to the platform, and therefore, increase the information available on traffic for all users.
- BONVOYAGE (2015-2018) is an H2020-funded project, which planned to develop and test a platform optimising multimodal door-to-door transport of passengers and goods. The platform integrates travel information, planning and ticketing services by automatically analysing non-real-time data from heterogeneous databases (on road, railway and urban transport systems); real-time measured data (traffic, weather forecasts); user profiles; and user feedback. BONVOYAGE trialled and demonstrated the platform and communication network in integrated, large-scale, real-life application scenarios, incorporated into the normal business operations of a transport operator.
- SPRINT (2018-2020) is an H2020-funded project, which seeks to evaluate the architectural solutions adopted in the Innovation Programme 4 (IP4) multimodal transport ecosystem projects and propose alternative architectural solutions and new software paradigms, in order to determine how current performance and scalability issues can be solved. This will be complementary to, and coherent with, the work performed by the parallel CONNECTIVE project (see below). The project will provide best practices and recommendations for the adoption of interoperability solutions, aiming to enhance IT2RAIL Interoperability Framework software components.
- Shift2MaaS (2018-2020) is a project funded by Shift2Rail, which aspires 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 and to support the introduction of Shift2Rail IP4 technology in the MaaS arena, analysing the needs of the different stakeholders involved.
- CONNECTIVE (2017-2022) is an H2020-funded project, which forms part of the Shift2Rail joint undertaking. It is the first initiative focused on accelerating the integration of new and advanced technologies into innovative rail product solutions. CONNECTIVE will provide a technical framework and a set of tools that will foster the digital transformation of rail and of the wider transport ecosystem in general. This will allow travellers to benefit from unprecedented multimodal travel experiences and will also improve the fit between supply and demand. CONNECTIVE will provide new levels of interoperability and seamless access to all transport data and services in a multimodal and distributed environment, while offering a common business intelligence to extract insights from the ecosystem, valuable for both users and service providers.

6.3.3 Achievements

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

- TIMON worked to address traffic accidents, congestion and the environmental impact of transport in cities through the development of a cooperative ecosystem. The project developed a cloud-based system, using data from transport users, open data and V2X communications. The system then used artificial intelligence techniques to process the data and provide real-time planning services to users through a smartphone application. Through this app, the project offered road status and planning alert services, as

well as enhancing the accuracy of vehicle and VRU positioning to improve safety. Two pilot projects were deployed in Helmond (the Netherlands) and the Ljubljana (Slovenia), with the latter attracting 238 end-users to engage with the TIMON app. Therefore, the project enhanced the development of the cloud-based system over its lifetime, from the initial basic research phase to demonstration phase.

— BONVOYAGE developed innovative door-to-door solutions to enable end-users to navigate easily, using any combination of transport modes. The solutions are driven by data, accounting for real-time conditions and user preferences. In addition to the benefit to end-users, BONVOYAGE developed digital infrastructure capable of clustering planning services and data sources, exploiting an innovative communication network, which collects and distributes the data required to optimise travel. The project developed a new communication network concept, known as an information-centric network; as well as generating OpenGeoBase, a decentralised storage system for building georeferenced mobile Apps. The project also adopted machine learning techniques for analysing data from user feedback and sensors. Therefore, BONVOYAGE has moved the digital infrastructure and communication network developed under the project from the basic research phase through to validation, developing an effective door-to-door App for mobility users.

— The concept of the Interoperability Framework is at the core of the Shift2Rail IP4, and it is the key concept for facilitating a seamless travel experience for users across borders and transport modes. A series of past and ongoing projects related to Shift2Rail IP4 (IT2Rail, ST4RT, GOF4R, CONNECTIVE) have developed, and are refining, a set of core concepts and technologies that are part of the Interoperability Framework. SPRINT will improve key aspects of the Shift2Rail Interoperability Framework, to bring the uptake of multimodal transport ecosystems, envisioned by IP4, closer to reality. The SPRINT project will promote a modal shift towards lower-carbon forms of transport, such as rail, by improving the intermodality between different transport modes. This will be achieved by enhancing the compatibility of interchange protocols across different applications, providing multimodal travel information, planning and booking services. As the project is still ongoing, defined results are yet to be achieved.

— 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 (i.e. Lisbon, Malaga and Central East Corridor), which are engaged in intermodality and MaaS. Shift2MaaS will demonstrate the benefits of IP4 through these pilot demonstrators of shared mobility services and passenger experience. The project will work to identify the technology needs required by key stakeholders, to ensure that passenger experience is prioritised and to validate use cases for the implementation of solutions. In addition, Shift2Maas will support COHESIVE, another Shift2Rail project that aims to integrate the various technological innovations developed in the other IP4 projects. As such, Shift2MaaS will design and test solutions developed by the COHESIVE project.

— Similarly to SPRINT, CONNECTIVE is part of Shift2Rail. The project aims to represent the technical foundation for Shift2Rail's IP4, which addresses the provision of IT solutions for railway services. CONNECTIVE will provide new levels of interoperability and seamless access to all transport data and services in a multimodal and distributed environment, while offering a common business intelligence to extract insights of the ecosystem, valuable for both users and service providers. As the project is still ongoing, defined results are yet to be achieved.

6.3.4 Implications for future research

This sub-theme covers projects with a specific focus on intermodal transport. The majority of projects are at the early basic research stage, with a few project technologies at the demonstration phase. This is largely reflected in the funding actions, with the majority of projects being funded by SME-2 and RIA.

A number of projects focus on traffic management at the city level. For example, TIMON addresses the key issues of safety, congestion and air pollution in cities, adopting artificial intelligence to offer real-time planning services to travel users, through an App. BONVOYAGE offers a similar solution, aiming to increase the ease of travel for users wishing to travel across multiple transport modes. Both of these projects, alongside similar projects, are at the basic research stage of development. Therefore, further research should be performed to advance these technologies, to demonstrate and deliver door-to-door solutions for end-users, through SME-2, CSA and IA funding actions. Solutions, such as mobile Apps, could provide useful developments in the field and further encourage intermodal travel.

In attempts to encourage a shift to rail travel, and more broadly encourage multimodality, projects such as SPRINT and CONNECTIVE, have focused on developing digital solutions to enhance the attractiveness of rail

transport as a mode of travel. These projects aim to enhance interoperability and shift the transport system to a lower carbon pathway. Further research could facilitate the advancement of these technologies from research to demonstration and implementation.

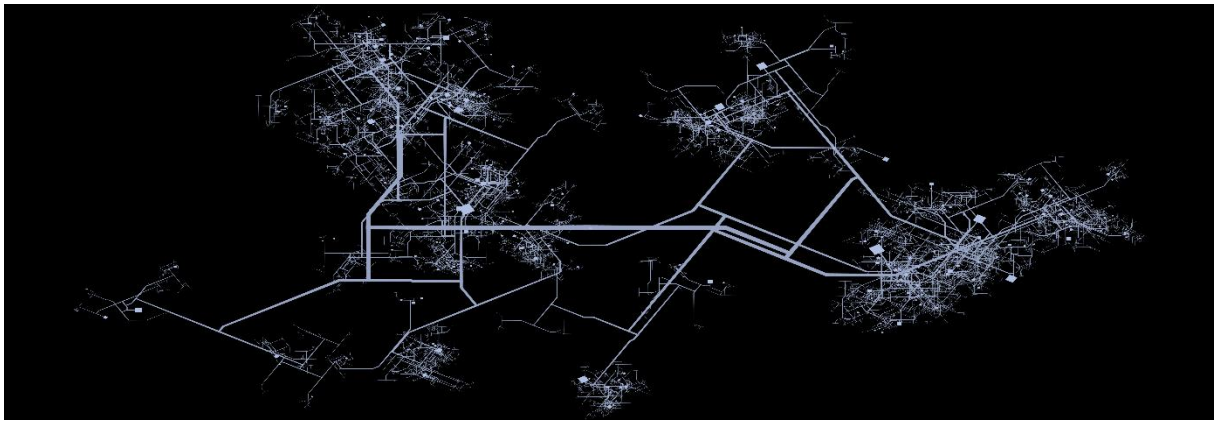
6.3.5 Implications for future policy development

The legal framework for the deployment of ITS and advanced NTM systems in the road sector is provided by the ITS Directive. The Directive aims to ensure the compatibility, interoperability and continuity of ITS solutions across the EU and sets out a number of policy measures to support the accessibility of EU-wide multimodal travel information for ITS users. Therefore, comprehensive EU-level funding is in place to drive research into intermodality forwards, providing the framework for projects such as BONVOYAGE.

In addition to this, the Shift2Rail program, under H2020, contributes significantly to the funding towards encouraging the movement of transport systems towards rail transport. Therefore, there is funding available to progress beyond the outcomes of projects such as Shift2MaaS, SPRINT and CONNECTIVE, enabling largescale testing and demonstration to occur.

As new traffic management systems and networks develop, it will be important for policy to ensure that there is a smooth interaction between public transport, urban freight and MaaS. Cities represent key hubs of intermodal 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. The European Commission's Urban Mobility Package supports research and development into urban mobility, through providing targeted funding for urban mobility measures, facilitating knowledge sharing and collaboration between urban mobility experts and ensuring that research and innovation focuses on the key issues facing urban areas, such as road safety and air pollution. Therefore, a comprehensive policy package is in place to support developments in traffic management system technologies at the city level, through financial assistance and foster collaboration between key stakeholder groups.

6.4 Sub-theme 4 – Travel hub management



This sub-theme covers projects which develop systems for effective travel hub management, i.e. ports, stations and car parks. It also includes projects which aim to develop travel hubs that are fit for future developments. In addition, the sub-theme covers projects aiming to deliver innovative parking management technologies, as these projects focus on the hub where travellers change mode from car to foot or public transport. Key technology themes under this sub-theme include, but are not limited to:

- Future-proof airports;
- Innovative solutions for station operations;
- Smart city hubs;
- Sustainable ecosystems for ports.

This sub-theme is important, as it aims to develop the technologies which facilitate improvements in the operations of key pieces of transport infrastructure, namely ports, airports, urban interchanges and train stations.

6.4.1 Overall direction of R&I

Travel hubs have become a key area of research under network and traffic management. With airports planning a 16 % increase in capacity by 2040 on average, which equates to four million more runway movements, technologies aiming to 'future-proof' airports to manage the increasing number of movements, have become key. Ports and train stations have witnessed a similar shift in focus, with research into these key nodes focusing on developing environmentally-sustainable, digitalised systems, capable of managing an increasing flux of passengers, as well as tackling broader safety and environmental concerns linked to the transport sector.

Further to this, the desire to encourage multimodality and a shift away from internal combustion engine (ICE) vehicles in cities has led to the establishment of smart city hubs, enhancing the ease of shifting from private vehicle use to public transport and active travel modes for transport users. Travel hub management has become a key area of research for both passenger and freight transport.

6.4.2 R&I activities

A total of 34 projects were assigned to this sub-theme. To provide a more detailed analysis, some key projects were selected to demonstrate the core areas of research undertaken relating to the NTM 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.

- INTERACTION (2013-2016) is an FP7-funded project, which planned to develop a new airport concept for turnaround coordination. The project proposed an evolution in airport operations towards a fully-integrated and coordinated management of processes, including passenger, baggage, freight and ramp operations. The INTERACTION concept aimed to be supported by advanced procedures and new operational concepts, innovative technologies and techniques, as well as enhanced information management and decision support tools. All of the solutions proposed by INTERACTION aimed to enhance safety and reduce the environmental impact of turnaround operations.
- PASSME (2015-2018) is an H2020-funded project, which sought to develop passenger-centric novel solutions (up to TRL 6) to help airports and airlines to address the anticipated increase in demand for commercial flights in Europe by 2050. The project aimed to reduce travel time by at least 60 minutes through integrating information between all stakeholders and transforming airport and aircraft operations to make passenger journeys more efficient, seamless and accessible. This required significant breakthrough solutions, such as a real-time passenger-centric system for managing passenger flows, that uses input from the airport and passengers to provide predictive analytics on passenger flows 20-30 minutes ahead of time.
- FASTPRK-2 (2016-2018) is an H2020-funded project, which aimed to develop a smart on-street parking solution, featuring enhanced services resulting from occupancy sensors and a system architecture. These optimise transport management through analysing diverse parking-related data, minimising maintenance costs and operational processes. As a result, it is estimated that an additional 190 million spaces are likely to become regulated in the near future, providing the market potential for FASTPRK-2 to succeed in Europe alone. The project aims to manage 60 million parking spaces in 2019. The project will develop cutting edge sensor technologies and tools, for applications which analyse diverse parking-related data, minimise maintenance costs and enhance the efficiency of operational processes.
- CITY-HUB (2012-2015) is an FP7-funded project, which intended to make urban interchanges more accessible to all users. The approach covered all aspects of an urban interchange, in order to increase the use of public transport, improve efficiency and propose a new business model. The project started by analysing best practice examples, developed by existing urban interchanges, including stakeholder engagement to identify travellers' priorities when transferring between modes. The aim was then to feed this information into the development of an integrated model and to develop a comprehensive set of methodological guidelines. The integrated model would then be validated through a set of European case studies, selected as demonstrators.
- PortForward (2018-2021) is an H2020-funded project, which aims to develop a holistic approach to port traffic management. This will lead to a smarter, greener and more sustainable port ecosystem, which will include the following features: the introduction of an Internet of Things (IoT) concept for port assets (i.e. infrastructure, vehicles, cargo, people) and a socio-economic analysis of the interface between the port with its surrounding area and the rest of the logistics value chain. The 'Port of the Future' will be able to

enhance sustainable development, manage the resources to be invested and ensure resources are employed effectively to facilitate a competitive advantage.

6.4.3 Achievements

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

— INTERACTION developed novel solutions for cost-efficient airport processes. It introduced a fully-integrated and coordinated management of passenger, baggage, freight and ramp operation processes. Using situation analysis as the basis, the INTERACTION team defined, designed, developed and validated 20 novel solutions for each airport process. The solutions were grouped into three categories: advanced procedures and new operational concepts; innovative technologies and techniques; and enhanced information management and decision-support tools. A business case and cost-benefit analysis identified the most promising improvements for each solution and the ideal scenario to maximise its potential. Airport operators, airlines, ground handlers and other aircraft service providers will benefit from INTERACTION's procedures, technologies and information tools. Improved turnaround times should also reduce the environmental impact of airport operations and enhance the service provided to passengers.

— The PASSME project has delivered industry-driven, passenger-centric novel solutions for passengers, airports and airlines to address the anticipated increase in demand for commercial flights in Europe by 2050. PASSME has reduced time spent at security and transformed the check-in and security process into a stress-free experience, using key touch points during check-in and boarding, as well as a real-time system for predictive analytics on passenger flows 20-30 minutes ahead of time. PASSME has redesigned the airport, to become passenger-centric. In waiting areas, specific design solutions have been incorporated, such as natural material finishes, to enhance the atmosphere of the airport. The Experience Lounge, together with video mapping for projections of landscapes and the natural environment, and information on boarding procedures and flights, could potentially reduce stress and improve boarding procedures.

— FASTPRK-2 has developed a system, which uses small sensors installed in each parking spot, which guide drivers via electric panels. Once a car is parked, the sensor wirelessly relays this information to the gateway. Utilising the system's mobility software platform, city managers obtain real-time analytics about parking occupancy. This information can then be used to predict parking occupancy, foresee availability and make planning more efficient. The system also integrates a list of innovative transport services, to facilitate operational intelligence. For instance, by predicting traffic flow, FASTPRK-2 can recommend alternative routes that take into account traffic and available public transport options. By automating parking reservations and online payments, FASTPRK-2 also benefits citizens through its smart parking app. The FASTPRK-2 sensor technology and mobility software platform have been validated through a widespread pilot campaign carried out in Spain, France, Belgium, Poland and Austria, involving stakeholders and key players from the smart parking industry. Following validation and demonstration, the project technologies have reached implementation through the delivery of its smart parking app.

— CITY-HUB contributed to developing a more efficient urban transport system. To achieve effective and sustainable urban transport interchanges, CITY-HUB created solutions to maximise coordination, information systems and business models. The focus was on the design of an integrated business model, which took into account all aspects of urban interchanges. During the first reporting period, the project team evaluated present circumstances in urban interchanges, and carried out stakeholder interviews and commuter surveys. It validated and tested the main factors that affect interchanges, such as efficient planning and design, accessibility, convenience and safety, moving away from the initial basic research phase. Researchers used the analysis of the current state of play and the results of the case studies as a starting point in the development of an efficient and smart design model for transport interchanges. They also assessed the operations, management, interconnectivity, information services and efficiency of urban transport interchanges.

— PortForward is an ongoing project, which is developing a 'Port of the Future', which must be oriented to port communities and have an operative strategic capability to work in line with European purposes. The project recognises the significance of sustainable development for ports, highlighting its significance for ports which aim to lead the industry in operational excellence, insightful collaboration through the supply chain, and safety, health and environmental practices. PortForward proposes a holistic approach, which will lead to a smarter, greener and more sustainable port ecosystem, and which will include the following features: the introduction of an Internet of Things (IoT) concept for port assets (infrastructure, vehicles,

cargo, people), and a socio-economic analysis of the port interface with its surrounding area, the port-city and the rest of the logistics value chain. As the project is still ongoing, it will be necessary to remain up-to-date with the project outputs as the project progresses further.

6.4.4 Implications for future research

This sub-theme covers a large number of projects with a specific focus on travel hub management, and the development of technologies which enhance the efficiency of operations at key infrastructure hubs. The majority of projects are at the early basic research stage, with several also at the validation, demonstration and implementation phases. This is reflected in the funding actions, with almost all of the projects funded under the SME-1, SME-2 and RIA funding actions.

Travel hub management possesses strong links with multimodality, particularly in cities. Several of the projects take place in urban environments, aiming to enhance the effectiveness and sustainability of transport hubs and interchanges in cities, such as CITY-HUB. In similar surroundings, a number of projects have focused on improving parking management solutions, in attempts to enhance traffic optimisation and encourage an easier shift between transport modes, such as FASTPRK-2. The city-specific projects tend to relate to encouraging multimodality, improving the ease of modal shift and enhancing the efficiency of transport operations in urban environments. As the majority of these projects are still in the early stages of development, future research would be beneficial to understand the effective operation of urban transport networks by increasing the capacity of city interchanges to facilitate efficient transport and encouraging increased multimodality, under IA and CSA funding actions.

A series of projects, such as INTERACTION and PASSME, focus on making airports 'future-fit'. PASSME acknowledges the predictions for growth in demand for commercial flights over the coming decades, and develops passenger-centric solutions to enable airports to manage growing numbers of visitors. Similarly, INTERACTION also aims to improve the efficiency of airport operations, through improving turnaround coordination. The technologies are at varying levels of development, so further development may be required to support efficient airport operations. Similarly to this, a few projects are focusing on enhancing the operation of ports, through aiming to draw upon digital infrastructure to advance the efficiency and sustainability of port ecosystems. These projects are also at the early stages of research. Therefore, advancing research on 'ports of the future', through bringing project technologies to validation and demonstration, will help to bring these solutions closer to implementation. As such, waterborne and aviation projects require similar future research strategies. There are minimal rail-focused projects. Therefore, further research into travel hubs for rail transport, building upon the energy metering and power supply solutions for railway stations researched by projects, such as IN2STEMPO, would be beneficial. As minimal projects have researched this area to date, SME-1 and RIA funding actions would be appropriate, to drive basic research and validation forwards.

6.4.5 Implications for future policy development

Currently, there is limited EU-level legislation or policy which specifically addresses the efficiency, sustainability and safety of travel hubs, such as ports and airports. However, under the SESAR deployment framework, ATM functionalities which require synchronised deployment are managed by the SESAR Deployment Manager, providing a partnership between airlines, airports and air navigation service providers. Therefore, there is support in place for technologies which require interaction between key aviation stakeholders, such as INTERACTION and PASSME. It is possible that developing similar organisational frameworks at other travel hubs (i.e. train stations, maritime ports), could facilitate more efficient operations of travel hubs and provide greater oversight of operations. This could help to encourage greater research into travel hubs for rail transport, which are currently lacking relative to other modes, whilst bolstering the support for port-related projects, such as PortForward.

CEF represents the overarching funding instrument for transport infrastructure projects, offering support for transport systems across all modes. Therefore, funding is in place to support developments of travel hubs. As cities continue to aim to shift towards more sustainable modes of transport, policy at the city-level will be important, to ensure that the foundations are in place to support the development of safe and sustainable city interchanges.

6.5 Sub-theme 5 – Freight transport and logistics

This sub-theme covers projects which aim to enhance the efficiency of freight and logistics. As such, it includes projects which aim to deliver vessel telematics and decision support tools, freight transport action plans and comprehensive logistics systems. Key technology themes under this sub-theme include, but are not limited to:

- Collaborative logistics ecosystems;
- Logistics-oriented telematics;
- Optimal cargo loading systems;
- Online container booking platforms.

This sub-theme is important, as it aims to develop technologies which engender improvements in the efficiency of freight transport operations, improving the ease of operations for employees in the logistics sector and enhancing the safety of freight operations across all modes.

6.5.1 Overall direction of R&I

Several areas of research have emerged as key to the development of freight transport and logistics. The development of digital infrastructure and architecture for supporting the development of innovative freight systems has been a key area of research in recent years. The technologies being researched are largely being applied to improve the efficiency and safety of freight transport, with particular focus on waterborne and road transport.

The projects under this sub-theme are primarily linked to multimodal, road and waterborne transport. 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.

6.5.2 R&I activities

A total of 62 projects were assigned to this sub-theme. To provide a more detailed analysis, some key projects were selected to demonstrate the core areas of research undertaken relating to the NTM 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.

- NEXTRUST (2015-2018) is an H2020-funded project, which planned to develop sustainable logistics through the development of trusted collaborative networks across the entire supply chain. The project aimed to develop networks, which integrate shippers and intermodal operators, bundling freight volumes and shifting freight from road to intermodal rail and waterways. The project aimed to build C-ITS cloud-based software, to support the re-engineering of the networks, improving the real-time utilisation of transport assets. Through pilot case studies, the project aimed to reduce greenhouse gas emissions associated with these deliveries by 40 % to 70 %.
- SELIS (2016-2018) is a H2020-funded project, which aimed to develop a platform for pan-European logistics applications, through establishing a unified agenda for sustainable logistics. SELIS aimed to deliver a platform for pan-European logistics applications, by embracing a wide spectrum of logistics

perspectives and creating an operational and strategic business innovation agenda for pan-European Green Logistics. The project aimed to establish a strong consortium of logistics sector stakeholders, capable of leveraging EU IP from over 40 projects to create a proof of concept for common communication and navigation.

— MODULUSHCA (2012-2016) is an H2020-funded project, which sought to lead the efforts on developing a roadmap for a fully interconnected logistics system in 2030. The roadmap aimed to address the steps required to change the logistics system, exploiting progress in digital and operational interconnectivities and drawing on existing expertise and infrastructure. The project aimed to enable operations to be developed with logistics units, adequate for modal and co-modal flows of fast-moving consumer goods, providing the basis for interconnected logistics systems for 2030.

— TELLISYS (2012-2015) is an FP7-funded project, which intended to develop an intelligent transport system for intermodal freight transport. The project aimed to promote the EU's objective of optimising the performance of intermodal logistics chains and to provide smooth interactions between different modes of transport. TELLISYS hoped to develop a system applicable to all modes, consisting of a modular set of volume-optimised and traceable MegaSwapBoxes, an adapted trailer and a tractor for road transport.

— PROMINENT (2015-2018) is an H2020-funded project, which planned to provide solutions to reduce the energy consumption and carbon footprint associated with inland waterway transport (IWT). The project focuses on the transition towards efficient, clean vessels. In addition, PROMINENT aimed to certify and monitor the emissions performance of vessels, develop echo sounder technology for optimised, energy-efficient navigation, and stimulate the integration of IWT into sustainable transport chains.

6.5.3 Achievements

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

— NEXTRUST refocused research activities, encouraging collaboration in the market. The logistics networks were validated through the delivery of pilot case studies, moving the project beyond its initial basic research phase. Major shippers were engaged as partners, including Mondelez, Panasonic and Unilever, as well as small and medium-sized enterprises (SMEs). The pilot studies covered the breadth of the supply chain, from raw materials to end consumers. The project helped to achieve improvements in asset utilisation, as well as improving the cost-effectiveness of logistics, developing a sustainable and competitive test space for European logistics.

— SELIS established a research and innovation environment, using living labs to facilitate continuous value creation, which support large-scale adoption of SELIS. Community Nodes are constructed by individual logistics communities, to facilitate the next generation of collaborative, responsive and agile green transportation chains. SELIS Community Nodes link with their participants' existing systems, through a secure infrastructure, and provide shared information and tools for data acquisition and use, according to a 'cooperation agreement'. Connected Nodes provide a distributed common communication and navigation platform for pan-European logistics applications. The SELIS Community Node concept represents the evolution of a longline of research in this area.

— MODULUSHCA developed a logistics system modelled on the Web. The EU-funded project provided a comprehensive set of concepts and developments towards a digital, operational and physical interconnected worldwide logistics network. To enable competitors to share their infrastructure and make full use of transport assets, a special set of modular boxes (M-Boxes) was developed and tested under real-world conditions. Box specifications aiming towards standardisation, such as collapsing functionalities or panel designs, have been assessed and innovative production methodologies, such as 3D printing, were employed for prototyping. The first laboratory tests for reliability, strength and potential faults involve supplying consumer goods such as body care and cleaning products to supermarkets and have been successfully executed in a distribution layout. The logistics system remained at the demonstration phase throughout the lifetime of the project.

— TELLISYS developed an intelligent transport system for innovative intermodal freight transport. The TELLISYS consortium engaged in market and lead user analysis, as well as establishing the definition, design and construction of each system component. The project developed a complete volume-optimised intermodal solution, including a family of new intermodal loading units developed to address different

use cases. The concept has been tested and evaluated, displaying financial benefits, such as cost savings of up to 15 % (relative to other current transport systems) and an increase in environmental efficiency (measured by $kgCO_2e$) of 25 %. Therefore, TELLISYS has generated a market-oriented intermodal technology concept, which generates new opportunities for intermodal transport in Europe, whilst meeting the EU's demand for more energy-efficient, low-emission logistics networks. The intelligent transport system has moved from the basic research phase, to the demonstration phase, as well as developing the business case required to ensure successful implementation.

— PROMINENT developed e-learning modules and echo sounder technologies concerning vessel stability, energy-efficient navigation and dangerous cargo. The project developed cost-effective solutions applicable to 70 % of the fleet. In relation to the current developments concerning modernisation and harmonisation of professional qualifications in inland navigation, PROMINENT analysed the comparison of the use of inland navigation ship-handling simulators to real-world situations. The echo sounder technologies moved from the basic research phase to validation and demonstration, with the intention to facilitate implementation by 2020.

6.5.4 Implications for future research

This sub-theme covers projects with a specific focus on freight transport and logistics. The majority of projects are at the early basic research stage, with a few projects also at the demonstration and implementation phases. This is reflected in the funding actions driving this research forwards, as SME-1 and RIA are the primary funding actions, which assist with the basic research and validation of technologies.

The projects focusing on logistics are varied in nature, yet a focus on sustainability is a common foundation for several projects. For example, NEXTRUST aimed to support the development of sustainable logistics, through establishing collaboration across the supply chain. In a similar vein, PROMINENT aimed to support decarbonisation through delivering energy and carbon management solutions, with a specific focus on IWT. In addition to this, the project had a training component, aiming to enhance the quality of the professional qualifications for employees in the IWT sector.

Beyond sustainability, a key focus for the logistics industry is the development of intelligent systems which support intermodality, with the capacity to be adopted across Europe. For example, TELLISYS aimed to develop an intelligent transport system for intermodal freight, whilst also addressing GHG emissions and efficiencies in freight. Building upon this, SELIS and MODULUSHCA aimed to develop interconnected logistics systems for intermodal travel across Europe, developing a unified agenda to align all Member States. Therefore, further research into the sustainability and intermodality of freight transport through CSA and IA funding actions, as well as a greater effort to establish an EU-wide approach to logistics management, will help to bring the technologies researched in these projects to implementation phase.

The vast majority of the projects under this sub-theme focus on multimodal travel, with minimal focus on rail freight. In regard to multimodality, the majority of projects focus on collaborative logistics ecosystems, which attempt to enhance efficiency and cohesion between multiple modes. These projects are almost entirely at the basic research development phase, requiring additional funding to bring promising technologies to the validation and demonstration stages. A focus on multimodal travel is followed by road and waterborne logistics. The majority of waterborne projects are at the early stages of basic research, with a focus on innovating logistics and improving efficiency, enhancing safety and reducing the magnitude of noise and air pollution. Therefore, further research aiming to validate and implement these technologies will bring a host of benefits to waterborne transport and the environment. Road transport projects are largely focused on tracking, smart logistics systems and sustainability, with a similar multitude of projects at the early stages of innovation. Therefore, continuing research into these thematic areas, to bring these technologies to fruition, would help to drive innovation and performance efficiency in the road sector. Due to the lack of research into rail transport within the projects selected to feature in this sub-theme, further research into rail logistics could be beneficial to facilitate improvements in the sector.

6.5.5 Implications for future policy development

The White Paper on Transport 2011 aims to create an e-Freight framework to allow tracing goods in real time and to ensure intermodal liability, which the European Commission has supported through a regulation on electronic freight transport information (COM(2018) 279). The aim of this regulation is to provide for a fully digital and harmonised environment for information exchanges between transport operators and authorities. Therefore, the policy is in place at the EU-level to support intermodal logistics and the harmonisation of

logistics systems for operators. This is important for projects, such as TELLISYS and MODULUSHCA, which developed intelligent logistics systems, reliant upon digital infrastructure and the provision of freight information.

In addition to this, the broader ERTMS, ITS and SafeSeaNet programs support developments in network and traffic management across the key transport modes which feature under this sub-theme. However, as an increasing number of projects focus on encouraging multimodality, such as SELIS and MODULUSHCA, it will be important to ensure that funding programs are open to supporting the development of interconnected logistics systems for intermodal travel across Europe.

With an increasing number of projects, such as PROMINENT, aiming to support decarbonisation through the development of transport and energy management solutions, it will be important to ensure that funding is available to support future actions aiming to support sustainable traffic management. As climate science updates, it will be important for both freight legislation and passenger transport legislation to remain up-to-date, to ensure that sufficient objectives for GHG emission reductions are set for all transport modes.

6.6 Sub-theme 6 – Sensors and detection systems

This sub-theme covers projects focusing on the use of innovative sensors, radars and other detection systems to improve traffic management. Therefore, it includes projects which focus on intelligence and surveillance systems, as well as communication technologies. Key technology themes under this sub-theme include, but are not limited to:

- Satellite communication technologies;
- Sensor technologies;
- Detection software;
- Intelligent surveillance systems.

This sub-theme is important, as it aims to produce technologies used for guidance, navigation and safety purposes. The development of sensor and satellite technologies across all modes of transport enable enhanced detection and encourage progression in the efficiency and safety of transport networks.

6.6.1 Overall direction of R&I

The use of sensors and radars is imperative to the facilitation of vehicle detection, whilst the development of satellite technologies is essential for vehicle communications and navigation. As these systems underpin the operation of network and traffic management systems, their development is crucial to enabling further innovation in the field.

Programmes, such as SafeSeaNet in the maritime sector, make use of satellite technologies to facilitate data exchange, linking authorities across Europe in an internet-based system. Similar use cases for satellite technologies can be witnessed across other transport modes. Sensor technologies have been applied for multiple uses, with on-board sensors applied to several projects relating to connected vehicles and communication technologies. The majority of the selected projects have focused on developing solutions to encourage safety and efficiency, by integrating improved detection and navigation systems to facilitate smoother travel. Over half of the projects allocated to this sub-theme are in the first stage of development. However, several projects also deliver prototypes and demonstrations, to display the potential for these technologies to be implemented in real-world applications.

6.6.2 R&I activities

A total of 88 projects were assigned to this sub-theme. To provide a more detailed analysis, some key projects were selected to demonstrate the core areas of research undertaken in the NTM 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.

— LOGIMATIC (2016-2019) is an H2020-funded project, which aimed to develop enhanced integration of the European Global Navigation Satellite System (EGNSS) and on-board sensors for port vehicle automation. LOGIMATIC proposed an ad-hoc advanced location and navigation solution to enable the automation of existing port vehicles with a significantly lower cost, which will allow short and medium-term investments, until the whole port fleet is renewed with autonomous vehicles in the long term. The project developed and demonstrated an innovative location and navigation solution for the automation of the operations of straddle carriers in container terminals.

— ALFA (2017-2019) is an H2020-funded project, which planned to develop advanced low flying aircrafts detection and tracking. The ALFA system bridges a detection capability gap, by drastically improving the situational awareness through the detection of low, small and slow manned and unmanned aircraft. ALFA is future-ready, as technologies for drone detection will be a part of the system, which will use heterogeneous, easy-to-deploy mobile sensors based on several novel technologies. All sensor data, augmented by other existing sources of information, will be combined, using evolved data fusion. This will provide accurate positional data for targets, including eventual indication of the air vehicle type and reliable prediction of its landing site.

— ENVISION (2018-2019) is an H2020-funded project, which sought to deliver an ATM application-oriented research project, under the SESAR 2020 Programme 'Enabling Aviation Infrastructure: CNS topic'. It aims at making use of technical progress in closed-circuit television (CCTV) cameras, technologies and image processing techniques. The project also aims to take advantage of reduced equipment costs, to provide regional and local airports with safe and affordable surface movements surveillance capabilities for air traffic control (ATC) and Airport Collaborative Decision Making (A-CDM) services. The project will assess the benefits of using this technical solution to feed A-CDM milestones and provide a surveillance display to airport stakeholders.

— INCEPTION (2017-2020) is an H2020-funded project, which intends to develop an innovative approach to the design of automatic flight control systems, supported by sensor-based control laws, with the ability of online reconfiguration following failure scenarios. Project INCEPTION focuses on researching and developing a coherent system for automatic flight control, and to test its performance in unmanned aircraft and evaluate its future applicability to general and commercial aviation. To accomplish these tasks, the INCEPTION consortium includes renowned universities, a private sector organisation which develops advanced inertial sensors and an SME, which engineers and operates its own unmanned aerial vehicle (UAV) fleet.

— COSMEMOS (2012-2014) is an FP7-funded project, which aimed to develop cooperative satellite navigation for meteo-marine modelling and services. It aimed to assess the scientific benefits of implementing cooperative meteo-marine data collection schemas, coupled with innovative on-board sensor architectures based on current and future Global Navigation Satellite Systems (GNSS) receivers. COSMEMOS aimed to develop several areas of innovation, including innovative use of GNSS signals for marine applications, improvements in meteorological models and local meteorological forecast capabilities and innovative data collection schemas and service models.

6.6.3 Achievements

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

— LOGIMATIC developed an advanced automated navigation solution, based on the integration of GNSS and sensors. The LOGIMATIC innovation is integrated in port vehicles, as part of an on-board navigation unit that communicates with a centralised geographic information system (GIS) to supervise and manage a port's entire fleet. Connected to all port vehicles via a wireless network, the system receives the current position of a platform and provides real-time progress on daily tasks. This solution is augmented by Galileo, Europe's single largest satellite constellation, and the European Geostationary Navigation Overlay Service (EGNOS), to improve the accuracy of its operations. The technology enables resource and space

optimisation, and allows extended and safer operations. The fleet management solution updates port services and minimises total travel distance, whilst the terminal operation system makes better use of port assets, labour and equipment.

— In line with its objective to develop advanced low-flying aircraft detection and tracking, ALFA is developing capabilities, which will be demonstrated in an operational context, using relevant targets and cooperation with two principal end-users. To date, an extensive study has been performed, researching operational aspects to combat drug trafficking. The architecture design has been detailed, including sensors and processing, information flow and data modelling, and provisions for connection with other systems. Radar technology has also been developed, which facilitates the detection of small aircraft in a sea clutter environment. In addition to this, software is being developed for detection, classification, tracking, behavioural analysis, threat analysis and landing site prediction, with first steps being made in preparation for the final demonstration. Although the project is ongoing, the project plan suggests that the low-flying aircraft detection and tracking technologies associated with the project are likely to move from the initial basic research phase, to demonstration, as the project progresses.

— Through testing in two airports, ENVISION is evaluating and demonstrating the operational, technical and economic feasibility of implementing CCTV and Light Detection and Ranging (LIDAR) technology to complement the use of automatic dependent surveillance-broadcast (ADS-B) on the ground, providing identification and positioning data in advanced-surface movement guidance and control systems (A-SMGCS). All trials, validation and demonstration activities were held in Muret airfield, which involved the deployment of video cameras and ADS-B receivers. The LIDAR module chosen for the project is not designed for outdoor environments; rather, it is transportable and deployed when necessary. Different scenarios, involving cooperative and non-cooperative targets, have been defined and several recording sessions have been completed to feed the technical work package developments. The LIDAR technologies developed currently remain at the demonstration development phase.

— INCEPTION is providing an enhanced level of safety for future aircraft, through employing self-reconfigurable mechanisms and control laws. The objective of the project is to predict and adapt to safe flight regimes of operation, even in the presence of unprecedented and unknown failures, and to enable the development of generic flight control systems, applicable to different aerial platforms. With the project ongoing, INCEPTION continues to focus on researching and developing a coherent system to enhance aircraft safety, and to test its performance in UAVs. As the project progresses, the plan is to move the automatic flight control system technologies from the basic research development phase, to validation and implementation, through considering the future applicability of the systems to general and commercial aviation.

— COSMEMOS primarily focused on the scientific use of cooperative meteorological data within the context of forecasting products. Its results constituted a fundamental input in assessing which technologies can better provide the added value required for the successful implementation of weather routing services, making it possible to evaluate service models and schemas to be implemented, as well as enabling assessments of the associated costs. Specifically, the project fulfilled its objective to develop new approaches for weather forecasting, including new ways to use GNSS signals to measure atmospheric conditions. COSMEMOS resulted in developments in several different areas of innovation, such as improvements of meteo-models and local meteo-forecast capabilities, innovative data collection schemas and service models. The project validated cooperative satellite navigation technologies which were developed, moving beyond the initial basic research stage to develop solutions which were ready for market.

6.6.4 Implications for future research

This sub-theme covers a significant number of projects which have a specific focus on sensor and satellite technologies, rather than the broader traffic management systems themselves. The majority of projects are at the early basic research stage, with several also at the demonstration phase (and a few at the validation and implementation phases). This is reflected in the funding actions supporting these projects, with the majority of projects falling under the SME-1 funding action. There are also several RIA and IA actions, which highlight the focus on basic research and demonstration respectively.

Under this sub-theme, there is a great amount of innovation and development of new sensor and satellite technologies and applications. The use cases vary significantly and span across all modes of transport. However, air transport has been allocated the most significant number of projects, including both aviation and drone technologies. For example, ALFA aimed to developed low-flying aircraft for detection and tracking

purposes, making use of sensor technologies. In another use case, INCEPTION draws upon sensors to develop an innovative approach for automatic flight control systems. In addition, ENVISION focuses on the demonstration of detection systems in airports. Therefore, as there is a substantial collection of projects focusing on the early stages of research into sensor technologies for aviation, there is scope to fund the validation and demonstration of more promising technologies, and bring together the existing expertise and knowledge developed under the several satellite and sensor-based technologies. Due to the focus on aviation transport, relative to the other modes, there is also greater scope to embark on research into sensor applications in road, rail and waterborne applications, through RIA and SME-1 actions.

Beyond sensors, a series of projects have focused on applying existing satellite systems, such as LOGIMATIC, which aimed to advance port vehicle automation through making use of navigation technologies. As the majority of projects are still at the early development phases, further research which could bring these applications to demonstration and implementation phase could be valuable.

6.6.5 Implications for future policy development

Given the early stage of market development for many of the sensor and communication technologies, innovation should not be restricted by policies which aim to standardise technology development. With several sensor and satellite technologies being developed with specific modes in mind, there is potential to examine whether applications can be made across multiple modes, to maximise the outputs from research and innovation.

Therefore, the legal framework for the deployment of ITS and advanced NTM systems in the road sector, which is provided by the ITS Directive, provides the policy necessary to support the development of sensor and communication technologies. In addition to this, programmes, such as SafeSeaNet in the maritime sector, make use of satellite technologies to facilitate data exchange, linking authorities across Europe in an internet-based system. Given the strong focus on aviation under this sub-theme, it is important that the SESAR deployment programme sufficiently encourages projects, such the automatic flight control system being developed by INCEPTION, to move beyond research to demonstration and implementation phases.

7 Conclusions

Focusing on selected EU funded projects starting from 2012 onwards, this report presents a comprehensive analysis of R&I in NTM in Europe. 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, key conclusions are:

Benefits of NTM research

— The benefits of improving NTM are considerable with studies showing positive examples for each mode of transport:

  - Road: Benefit-cost ratios ranging from 2 to 8 for implementing C-ITS systems across the EU.
  - Aviation: Around EUR 12 billion performance gains for an investment of about EUR 4 billion in the period 2015 – 2024.
  - Rail: A positive business case for the implementation of ERTMS on the core network corridors.
  - Waterborne: Optimised travel planning and a strong reduction in inefficient anchoring time.

— These benefits are a key rationale for supporting NTM through R&I funding.

Overview on European NTM Research funding

— Under FP7 and H2020 over EUR 1.95 billion has been invested in NTM research projects. This includes EUR 1.3 billion of EU funds and about EUR 0.6 billion of own contributions by beneficiary organisations.

— A total of 2 335 unique organisations participated in FP7 and/or H2020 projects on NTM. Some organisations focus exclusively on NTM research in one mode of transport, whereas others conduct research across modes. Of the top 15 beneficiaries, 15 are active in aviation, 4 in road, 5 in multimodal, 5 in rail, and 4 in waterborne transport.

— Spending on NTM research under H2020 peaked in the beginning of 2018. Aviation research received most funding, while waterborne transport received the smallest amount of funds.

— The technology analysis highlights clusters that are researched in FP programmes at different development phases.

— The text analysis on scientific research showed that the number of publications in NTM generally shows a positive trend, with ITS receiving most interest.

Project related findings by sub-theme

On the traffic management systems sub-theme:

— The majority of projects are at the early basic research stage of development, with several also at the demonstration and implementation phases. Funding for the projects under this sub-theme has been provided by SME-1 (for several, relatively small, projects) and RIA, reflecting the early stages of development of the majority of projects at inception, as well as other actions that have supported taking the technologies through towards demonstration and implementation.

— Safety is a key foundation for several projects under this sub-theme. For example, CONTAIN, which also falls under the sub-theme on freight transport and logistics, aims to enhance security and safety in container management. As safety remains a key theme for EU-funded projects, as well as a key objective for EU-level policy, it is important that future research continues to develop innovative solutions to improving the safety of transport networks across all modes.

— Although the majority of projects under this sub-theme are funded by H2020 and FP7, CEF is the key funding instrument implementing TEN-T policy in Europe. This includes ITS for road and ERTMS for railways, which relate to connectivity and traffic management in road and rail transport, respectively. The next CEF programme (2021-2027) is expected to focus on making transport more connected, sustainable, inclusive, safe and secure, which aligns with the current themes of the projects explored. Therefore, as the CEF programme develops, it is expected that funding for demonstration and largescale testing

projects will support innovation across the key thematic areas of safety, sustainability and traffic optimisation.

On the air traffic management sub-theme:

— The majority of projects are at the early basic research stage, with several also at the validation phase. Therefore, the vast majority of projects which fall under this sub-theme explore new technologies for advancing ATM, with few projects focusing on the implementation of existing concepts. The majority of projects are currently funded under the RIA action.

— Several projects focus on improving risk management and safety. Some of these projects include demonstrations of technologies developing during the project, to test the capacity of new systems to accurately and effectively improve safety across the span of air traffic operations. Therefore, bringing these technologies to fruition, upon successful demonstration through the CSA and IA actions, will provide an impactful contribution to aviation safety.

On the intermodal management systems sub-theme:

— The majority of projects are at the early basic research stage, with a few project technologies at the demonstration phase. This is largely reflected in the funding actions, with the majority of projects being funded by SME-2 and RIA.

— In attempts to encourage a modal shift, projects focused on developing digital solutions to enhance the attractiveness of rail transport as a mode of travel. These projects aim to enhance interoperability and shift the transport system to a lower carbon pathway. Further research could facilitate the advancement of these technologies from research to demonstration and implementation.

— The legal framework for the deployment of ITS and advanced NTM systems in the road sector is provided by the ITS Directive. The Directive aims to ensure the compatibility, interoperability and continuity of ITS solutions across the EU and sets out a number of policy measures to support the accessibility of EU-wide multimodal travel information for ITS users. Therefore, comprehensive EU-level funding is in place to drive research into intermodality forwards.

On the travel hub management sub-theme:

— The majority of projects are at the early basic research stage, with several also at the validation, demonstration and implementation phases. This is reflected in the funding actions, with almost all of the projects funded under the SME-1, SME-2 and RIA funding actions.

— Travel hub management possesses strong links with multimodality, particularly in cities. Several of the projects take place in urban environments, aiming to enhance the effectiveness and sustainability of transport hubs and interchanges in cities. As the majority of these projects are still in the early stages of development, future research would be beneficial to understand the effective operation of urban transport networks by increasing the capacity of city interchanges to facilitate efficient transport and encouraging increased multimodality, under IA and CSA funding actions.

— CEF represents the overarching funding instrument for transport infrastructure projects, offering support for transport systems across all modes. Therefore, funding is in place to support developments of travel hubs. As cities continue to aim to shift towards more sustainable modes of transport, policy at the city-level will be important, to ensure that the foundations are in place to support the development of safe and sustainable city interchanges.

On the freight transport and logistics sub-theme:

— The majority of projects are at the early basic research stage, with a few projects also at the demonstration and implementation phases. This is reflected in the funding actions driving this research forwards, as SME-1 and RIA are the primary funding actions, which assist with the basic research and validation of technologies.

— The projects focusing on logistics are varied in nature, yet a focus on sustainability is a common foundation for several projects. Beyond sustainability, a key focus for the logistics industry is the development of intelligent systems which support intermodality, with the capacity to be adopted across Europe.

— The vast majority of the projects under this sub-theme focus on multimodal travel, with minimal focus on rail freight. In regard to multimodality, the majority of projects focus on collaborative logistics

ecosystems, which attempt to enhance efficiency and cohesion between multiple modes. These projects are almost entirely at the basic research development phase, requiring additional funding to bring promising technologies to the validation and demonstration stages. A focus on multimodal travel is followed by road and waterborne logistics. Research into rail transport under this sub-theme is relatively small.

On the sensors and detection systems sub-theme:

- The majority of projects are at the early basic research stage, with several also at the demonstration phase (and a few at the validation and implementation phases). This is reflected in the funding actions supporting these projects, with the majority of projects falling under the SME-1 funding action.
- Under this sub-theme the use cases vary significantly and span across all modes of transport. However, air transport has been allocated the most significant number of projects, including both aviation and drone technologies.
- A series of projects have focused on applying existing satellite systems, such as LOGIMATIC, which aimed to advance port vehicle automation through making use of navigation technologies. As the majority of projects are still at the early development phases, further research which could bring these applications to demonstration and implementation phase could be valuable.

The analyses performed in this report are subject to some limitations, namely:

- TRIMIS focuses on publicly funded projects, therefore private initiatives are not fully considered. This makes that the report provides a distinctive perspective on transport R&I.
- On Section 5, the technology identification and the corresponding development phase assessment is still on going, and the technology taxonomy is being updated. Likewise, the methodology behind the text analysis on NTM academic research shall be improved.

Altogether, this report provides a comprehensive and up-to-date review of NTM R&I across Europe. These findings can be leveraged by various actors that are involved in shaping the future of research on network and traffic management systems.

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List of abbreviations and definitions

ALT	Alternative Energy
AT	Austria
ATP	Automatic Train Protection System
BE	Belgium
BG	Bulgaria
CAT	Connected & Automated Transport
CAM	Connected and automated mobility
CCAM	Cooperative connected and automated mobility
CCNR	Central Commission for the Navigation of the Rhine
CEDR	Conference of European Directors of Roads
CEF	Connecting Europe Facility
C-ITS	Cooperative Intelligent Transport Systems
CO_2	Carbon dioxide
CORDIS	Community Research and Development Information Service
COST	Co-Operations in Science and Technology
CY	Cyprus
CZ	Czech Republic
DE	Germany
DG MOVE	Directorate-General for Mobility and Transport
DG RTD	Directorate-General for Research and Innovation
DK	Denmark
DOT	Department of Transportation
DSM	Digital Single Market
DSRC	Dedicated short-range communication
EC	European Commission
EE	Estonia
EL	Greece
ELT	Electrification
ERRAC	European Rail Research Advisory Council
ERTMS	European Rail Traffic Management System
ERTRAC	European Road Transport Research Advisory Council
ES	Spain
ETCS	European Train Control System
EU	European Union
EU-13	Group of 13 EU countries: Bulgaria (BG), Czech Republic (CZ), Croatia (HR), Cyprus (CY), 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
FR	France
FTA	Federal Transit Administration
GNSS	Global Navigation Satellite Systems
GSM	Global System for Mobile Communications
GSM-R	Global System for Mobile Communications – Railway
H2020	Horizon 2020 Framework Programme
HR	Croatia
HU	Hungary
IE	Ireland
IEC	International Electrotechnical Commission
INF	Infrastructure
IoT	Internet of Thing
ISAD	Infrastructure Support Levels for Automated Driving
IT	Italy
ITS	Intelligent Transport Systems
JPO	Joint Program Office
JRC	Joint Research Centre
LIDAR	Light detection and ranging
LT	Lithuania
LTA	Land Transport Authority
LU	Luxembourg
LV	Latvia
MaaS	Mobility-as-a-Service
MS	Member States
MT	Malta
NASA	National Aeronautics and Space Administration
NETT	New and emerging technologies and trends
NL	Netherlands
NTM	Network & Traffic Management
ODS	Obstacle Detection System
PL	Poland
PT	Portugal
REGEX	Regular expressions
R&I	Research and innovation
RO	Romania
SE	Sweden
SESAR	Single European Sky ATM Research
SI	Slovenia

SK	Slovakia
SME	Small Medium Enterprise
SMMT	Society of Motor Manufacturers and Traders
SMO	Smart Mobility
STRIA	Strategic Transport Research and Innovation Agenda
TEN	Trans-European network
TEN-T	Trans-European transport network
TRIMIS	Transport Research and Innovation Monitoring and Information System
TRL	Technology readiness level
UK	United Kingdom
US	United States
VDM	Vehicle Design & Manufacturing
WG	Working Group

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Annexes

Annex 1: Project table

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.

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
2014-EU-TM-0136-M	SESAR Deployment Programme Implementation	2014-2020	CEF		Y				
45HC.com	45HC.com	2016-2016	H2020-EU.3.4.					Y	
5G-DRIVE	5G DRIVEn Resource Efficient Mobile Aggregation Networks	2014-2020	H2020-EU.1.3.	Y					
AAL2	Augmented Approaches to Land 2	2018-2020	H2020-EU.3.4.				Y		
ADAPT	Advanced prediction models for flexible trajectory-based operations	2018-2019	H2020-EU.3.4.		Y				
AEOLIX	Architecture for EurOpean Logistics Information eXchange	2016-2019	H2020-EU.3.4.					Y	
AERFOR	Advanced Forecasting System for Proactive Airport Passenger Flow Management	2016-2018	H2020-EU.3.4.				Y		
AERFOR	Proactive Passenger Flow Management for Airports with an Advanced Forecasting System	2014-2015	H2020-EU.3.4.				Y		

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
AEROBI	AErial RObotic System for In-Depth Bridge Inspection by Contact	2015-2018	H2020-EU.2.1.						Y
AGEN	Atomic Gyroscope for Enhanced Navigation	2012-2014	FP7-TRANSPORT						Y
AGENT	Adaptive self-Governed aerial Ecosystem by Negotiated Traffic	2016-2018	H2020-EU.3.4.						Y
AGILE	Aircraft 3rd Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts	2015-2018	H2020-EU.3.4.		Y				
AIRBEAM	AIRBorne information for Emergency situation Awareness and Monitoring	2012-2015	FP7-SECURITY						Y
Airline Team NCM	Airspace User support to the development of Network Collaborative Management	2018-2020	H2020-EU.3.4.		Y				
Airline Team xStream	Airspace User Support to Arrival Management	2018-2020	H2020-EU.3.4.				Y		
AIRPASS	Advanced Integrated RPAS Avionics Safety Suite	2017-2019	H2020-EU.3.4.		Y				
Airport IQ	Situation-Aware Mobile Platform for Airport Collaborative Decision-Making	2015-2017	H2020-EU.3.4.				Y		

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
ALFA	Advanced Low Flying Aircrafts Detection and Tracking	2017-2019	H2020-EU.3.7.						Y
AMIDST	Analysis of Massive Data Streams	2014-2016	FP7-ICT						Y
AMPWISE	Autonomous Wireless Current Sensor for Aircraft Power Lines	2018-2021	H2020-EU.3.4.						Y
ANIMA	Aviation Noise Impact Management through Novel Approaches	2017-2021	H2020-EU.3.4.		Y				
APACHE	Assessment of Performance in current ATM operations and of new Concepts of operations for its Holistic Enhancement	2016-2018	H2020-EU.3.4.		Y				
AQUO	Achieve QUieter Oceans by shipping noise footprint reduction	2012-2015	FP7-TRANSPORT					Y	
ARMOURS	Antenna and Front-End Modules for Public Regulates Service Applications	2012-2014	FP7-TRANSPORT						Y
ATM4E	Air Traffic Management for environment	2016-2018	H2020-EU.3.4.		Y				
AUDIO	Airspace User supporting Demonstrations of Integrated Airport Operations	2019-2021	H2020-EU.3.4.				Y		

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
AURORA	Advanced User-centric efficiency metRics for air traffic perfORmance Analytics	2016-2018	H2020-EU.3.4.		Y				
AUTOCITS	AUTOCITS: REGULATION STUDY FOR INTEROPERABILITY IN THE ADOPTION THE AUTONOMOUS DRIVING IN EUROPEAN URBAN NODES	2018-2019	CEF	Y					
Awareness Africa	Awareness in Africa: Disseminating Knowledge on EGNOS and Galileo in Africa to Foster Local and Regional Development	2012-2013	FP7-TRANSPORT						Y
AW-Drones	Contributing to a well-reasoned set of Airworthiness Standards for mass-market drones	2019-2021	H2020-EU.3.4.		Y				
B4CM	Blockchains as a distributed ledger for attribution of RCM data in rail	2018-2021	Shift2Rail			Y			
BEST	Achieving the BEnefits of SWIM by making smart use of Semantic Technologies	2016-2018	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				

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
BIRDWATCH	BIRDWATCH, The first integral and modular mobility and security solution for smart parking management	2015-2015	H2020-EU.3.4.				Y		
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			
BrainWorkloadReader	Generation of a business plan for the production of a compact and reliable device able to measure in real-time the cerebral workload state of high responsibility operators in the transport domain	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		
BX Platform	BX Platform Converting real time data into more efficient trucking operations	2018-2019	H2020-EU.2.3.					Y	
CargoList	Freight Auction, reinvented	2016-2016	H2020-EU.3.4.					Y	
CATS	City Alternative Transport System	2018-2020	FP7-TRANSPORT	Y					

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
CELSO	Low-cost and high-performance pocket Automated Vehicle Monitoring system for Public Transport	2017-2019	H2020-EU.3.4.	Y					
CEWITT	Low Cost and low Energy GNSS-based WIreless Tag for asset Tracking and monitoring	2012-2014	FP7-TRANSPORT						Y
CHARM	Common Highways Agency Rijkswaterstaat Model	2017-2021	FP7-ICT	Y					
CIPTEC	Collective Innovation for Public Transport in European Cities	2016-2018	H2020-EU.3.4.	Y					
CITRUS	C-ITS for Trucks	2016-2019	CEF					Y	
CITY-HUB	City-Hub	2012-2015	FP7-TRANSPORT				Y		
CIVITAS CITYLAB	City Logistics in Living Laboratories	2015-2018	H2020-EU.3.4.					Y	
CIVITAS CITYLAB	CIVITAS CITYLAB	2015-2018	H2020-EU.3.4.					Y	
CIVITAS ECCENTRIC	Innovative solutions for sustainable mobility of people in suburban city districts and emission free freight logistics in urban centres.	2016-2020	H2020-EU.3.4.					Y	

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
CLASS	CLear Air Situation for uaS: Maturing ground based technologies for a real-time Unmanned Aerial System Traffic Management System (UTMS) to monitor and separate Unmanned Aerial System (UAS) traffic	2017-2019	H2020-EU.3.4.						Y
CLOUD-VAS	Cloud based Vessel Allocation Decision Support System for Vessel Chartering	2015-2017	H2020-EU.3.4.					Y	
CLUSTERS 2.0	Open network of hyper connected logistics clusters towards Physical Internet	2017-2020	H2020-EU.3.4.					Y	
CO-ACTIVE	CO-modal journey re-ACcommodation on associated Travel serVices	2016-2018	H2020-EU.3.4.			Y			
COCONET	Towards COast to COast NETworks of marine protected areas (from the shore to the high and deep sea), coupled with sea-based wind energy potential.	2016-2018	FP7-KBBE	Y					
COCTA	Coordinated capacity ordering and trajectory pricing for better-performing ATM	2016-2018	H2020-EU.3.4.		Y				
COG-LO	COGnitive Logistics Operations through secure, dynamic and ad-hoc collaborative networks	2018-2021	H2020-EU.3.4.					Y	

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
Cohesive	COHErent Setup and Demonstration of Integrated Travel SerVices	2016-2018	H2020-EU.3.4.	Y					
COLDTRACK	New cloud-base SW for ensuring the Cold Chain during Food Transportation	2017-2017	H2020-EU.3.4.					Y	
COLLOGISTICS	Express Delivery end-to-end Management System through collaborative intelligence.	2015-2016	H2020-EU.3.4.					Y	
COMPAIR	COMPetition for AIR traffic management	2016-2018	H2020-EU.3.4.		Y				
COMPANION	Cooperative dynamic formation of platoons for safe and energy-optimized goods transportation	2013-2016	FP7-ICT					Y	
CONNECTA	CONtributing to Shift2Rail's NExt generation of high Capable and safe TCMS and brAkes. Phase 1.	2019-2021	H2020-EU.3.4.	Y					
CONNECTA-2	Cost-efficient and reliable trains, including high-capacity trains and high-speed trains	2016-2018	Shift2Rail	Y					
CONNECTIVE	Connecting and Analysing the Digital Transport Ecosystem	2017-2022	H2020-EU.3.4.			Y			
CONTAIN	Container Security Advanced Information Networking	2016-2018	FP7-SECURITY	Y					

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
COPTRA	COmbining Probable TRAjectories	2016-2018	H2020-EU.3.4.		Y				
CORUS	Concept of Operations for EuRopean UTM Systems	2017-2019	H2020-EU.3.4.						Y
COSMEMOS	COoperative Satellite navigation for MEteo-marine MOdelling and Services	2012-2014	FP7-TRANSPORT						Y
COTTON	Capacity Optimisation in TrajecTory-based OperatioNs	2018-2019	H2020-EU.3.4.					Y	
C-Roads Belgium/Flanders	C-Roads Belgium/Flanders	2016-2018	CEF	Y					
C-ROADS Hungary	C-ROADS Hungary	2016-2018	CEF Transport	Y					
C-Roads Slovenia 2	C-Roads Slovenia 2	2016-2018	CEF Transport	Y					
CWT	Clearview Trade - Cloud based collaborative custom system	2015-2016	H2020-EU.3.4.					Y	
CYRail	Cybersecurity in the RAILway sector	2016-2016	H2020-EU.3.4.	Y					
D3IMPACT	Data-driven decisions for intelligent management of public transportation	2016-2018	H2020-EU.3.4.	Y					

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
DAPS	Drone Alarm and Protection System	2016-2016	H2020-EU.3.7.		Y				
DART	Data-driven AiRcraft Trajectory prediction research	2016-2018	H2020-EU.3.4.		Y				
Day-by-day	Day-by-Day Short-Term Traffic Forecasts for Road Concessions (top app)	2018-2020	H2020-EU.3.4.	Y					
DETECTOR	Detection, Evaluation and Characterisation of Threats to Road applications	2012-2013	FP7-TRANSPORT						Y
DILECO	DIgitalization of ground-testing Life cycle with ECO design criteria	2018-2020	H2020-EU.3.4.		Y				
DocksTheFuture	Developing the methodology for a coordinated approach to the clustering, monitoring and evaluation of results of actions under the Ports of the Future topic	2018-2020	H2020-EU.3.4.				Y		
Domino	Novel tools to evaluate ATM systems coupling under future deployment scenarios	2018-2019	H2020-EU.3.4.		Y				
DORA	Door to Door Information for Airports and Airlines	2015-2018	H2020-EU.3.4.				Y		

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
Early Warning Intelligent System for Road Transportation Risks	Early Warning Intelligent System for Road Transportation Risks	2016-2018	CEF Transport						Y
Easy-OBU	Enhanced (EGNOS/EDAS) Accuracy SYstem with GNSS Outage Bridging Unit	2012-2014	FP7-TRANSPORT					Y	
EATS	ETCS Advanced Testing and Smart Train Positioning System	2012-2016	FP7-TRANSPORT						Y
EBSF_2	European Bus System of the Future 2	2018-2019	H2020-EU.3.4.	Y					
E-COMPLIANCE	A European Maritime e-Compliance Cooperation Model	2013-2016	FP7-TRANSPORT			Y			
ECOSSIAN	European Control System Security Incident Analysis Network	2014-2017	FP7-SECURITY			Y			
EEGS2	EGNOS EXTENSION TO EASTERN EUROPE: APPLICATIONS	2012-2013	FP7-TRANSPORT						Y
EfficienSea 2	EfficienSea 2 - Efficient, Safe and Sustainable Traffic at Sea	2018-2021	H2020-EU.3.4.	Y					
E-HIMALAYA	extended-HIgh performance MAss market GNSS receiver muLti stAndard readY for mArket	2012-2014	FP7-TRANSPORT						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
e-Impact	e-Freight Implementation Action	2015-2018	CEF					Y	
EMAR	e-Maritime Strategic Framework and Simulation based Validation	2018-2021	FP7-TRANSPORT	Y					
EMPHASIS	EMPowering Heterogeneous Aviation through cellular SIgnalS	2018-2020	H2020-EU.3.4.						Y
Engage	Knowledge Transfer Network proposed in response to the SESAR-ER3-01-2016 Call	2018-2021	H2020-EU.3.4.		Y				
ENIGMA	Supervisor Control for ENhanced electrIcal enerGy MAnagement	2018-2021	H2020-EU.3.4.		Y				
ENVISION	Enhanced Situational Awareness through Video Integration with ADS-B Surveillance Infrastructure on Airports	2018-2019	H2020-EU.3.4.						Y
ePatriot	Evolved Sky Patriot - Phase 1 Feasibility Study	2017-2017	H2020-EU.3.7.						Y
ERSAT GGC	ERTMS on SATELLITE Galileo Game Changer	2017-2019	H2020-EU.3.4.						Y
ETALON	Energy harvesTing for signAlLing and cOmmunicatioN systems	2017-2020	H2020-EU.3.4.					Y	
E-TRACK	EGNOS and EDAS Enhanced Tracking of Animal Movement and Behaviour	2012-2013	FP7-TRANSPORT						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
EUNADICS-AV	European Natural Airborne Disaster Information and Coordination System for Aviation	2016-2019	H2020-EU.3.4.		Y				
EUNOIA	Evolutive User-centric Networks for Intraurban Accessibility	2016-2019	FP7-ICT	Y					
EVOAtm	Evolutionary ATM. A modelling framework to assess the impact of ATM evolutions	2018-2019	H2020-EU.3.4.		Y				
FASTPRK	Enhanced on-street parking management system	2015-2016	H2020-EU.3.4.				Y		
FASTPRK-2	Enhanced on-street parking management system (2)	2016-2018	H2020-EU.3.4.				Y		
FAST-TRACKS	Fast rAdio technologieS for uninterrupTed TRAin to traCKside communications	2018-2019	H2020-EU.3.4.	Y					
FAST-TRACKS 2	Fast rAdio technologieS for uninterrupTed TRAin to traCKside communicationS (2)	2018-2020	H2020-EU.3.4.	Y					
FilGAPP	Filling the gap in GNSS Advanced Procedures and oPerations	2012-2014	FP7-TRANSPORT						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
FIVER	Innovative solution for FMS computed trajectories validation by means of pilot actions emulation, comparison with PANS-OPS criteria and data mining techniques.	2018-2020	H2020-EU.3.4.		Y				
FLAMINGO	Fulfilling enhanced Location Accuracy in the Mass-market through Initial GalileO services	2017-2020	H2020-EU.3.4.						Y
FLYSEC	Optimising time-to-FLY and enhancing airport SECurity	2015-2018	H2020-EU.3.7.				Y		
FORJET2035	ATS Level Business Jet 2035 Forecast	2017-2018	H2020-EU.3.4.		Y				
FORROT2035	ATS Level Rotorcraft 2035 Forecast	2017-2018	H2020-EU.3.4.		Y				
FORSAT2035	ATS Level SAT 2035 Forecast	2017-2018	H2020-EU.3.4.					Y	
FR8HUB	Real-time information applications and energy efficient solutions for rail freight	2017-2020	H2020-EU.3.4.				Y		
FR8RAIL	Development of Functional Requirements for Sustainable and Attractive European Rail Freight	2016-2019	H2020-EU.3.4.					Y	
Future Sky Safety	Future Sky Safety	2015-2019	H2020-EU.3.4.		Y				

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
GAIN	GAIN - Galileo for Interactive Driving	2012-2014	FP7-TRANSPORT						Y
GAINS	General Aviation Improved Navigation and Surveillance	2018-2019	H2020-EU.3.4.		Y				
GAL	GAL: Galileo for Gravity	2012-2014	FP7-TRANSPORT						Y
GaLoROI	Galileo Localization for Railway Operation Innovation	2012-2014	FP7-TRANSPORT						Y
GATE4RAIL	Advanced traffic management and control systems	2018-2020	Shift2Rail - Shift2Rail						Y
GATEMAN	GNSS NAVIGATION THREATS MANAGEMENT	2018-2019	H2020-EU.3.4.						Y
GAUSS	Galileo-EGNOS as an Asset for UTM Safety and Security	2018-2021	H2020-EU.2.1.						Y
GECKO	Governance principles and mEthods enabling deCision maKers to manage and regulate the changing mObility systems	2017-2018	H2020-EU.3.4.	Y					
GENIUS	GNSS Education Network for Universities and IndustrieS	2012-2016	FP7-TRANSPORT						Y
GEOPAL	GNSS-based Planning system for Agricultural Logistics	2012-2014	FP7-TRANSPORT					Y	

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
GlobILS	Global Platform for Indoor Location Services	2016-2018	H2020-EU.3.4.			Y			
GOEASY	GalileO-based trustEd Applications for health and SustainabilitY	2017-2020	H2020-EU.3.4.						Y
GoSAFE RAIL	Global Safety Management Framework for RAIL Operations	2016-2019	H2020-EU.3.4.						Y
GRACE	GaN mm-wave Radar Components Embedded	2018-2020	H2020-EU.3.4.						Y
GRADE	GNSS Solutions for Increased GA and Rotorcraft Airport Accessibility Demonstration	2018-2019	H2020-EU.3.4.				Y		Y
GRIMASSE	General aviation Rescue capacity IMprovement for the worldwide Adoption of a Safe Solution based on European GNSS	2017-2019	H2020-EU.3.4.						Y
GSP	Galileo Signal Priority	2012-2014	FP7-TRANSPORT						Y
H2H	EGNSS Hull-to-Hull	2017-2020	H2020-EU.3.4.						Y
Handheld	Handheld device with innovative compact antenna for professional GNSS applications	2012-2013	FP7-TRANSPORT						Y
HEDGE NEXT	Helicopter Deploy GNSS in Europe NEXT	2012-2014	FP7-TRANSPORT						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
HyTunnel-CS	PNR for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces	2017-2018	H2020-EU.3.4.	Y					
IBiS	Full scale demonstration of an Innovative solution for Baggage Handling Systems at airports (IBiS)	2017-2017	H2020-EU.3.4.				Y		
ICARUS	Innovative changes in Air Transport. Research for Universally Designed Services	2012-2014	FP7-AAT		Y				
ICONET	New ICT infrastructure and reference architecture to support Operations in future PI Logistics NETworks	2018-2021	H2020-EU.3.4.					Y	
iCROSS	Intelligent Portable ContROl SyStem	2016-2019	H2020-EU.3.7.						Y
ICSI	Intelligent Cooperative Sensing for Improved traffic efficiency	2012-2015	FP7-ICT						Y
i-DREAMS	Safety tolerance zone calculation and interventions for driver-vehicle-environment interactions under challenging conditions	2019-2022	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			

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
IMPETUS	Information Management Portal to Enable the inTegration of Unmanned Systems	2017-2019	H2020-EU.3.4.		Y				
IN2STEMPO	Innovative Solutions in Future Stations, Energy Metering and Power Supply	2017-2022	H2020-EU.3.4.				Y		
INCEPTION	Incremental Nonlinear flight Control supplemented with Envelope ProtecTION techniques	2017-2020	H2020-EU.3.4.						Y
InDrive	InDrive : Automotive EGNSS Receiver for High Integrity Applications on the Drive	2016-2017	H2020-EU.3.4.						Y
inLane : Lane Navigation Technology	Low Cost GNSS and Computer Vision Fusion for Accurate Lane Level Navigation and Enhanced Automatic Map Generation	2016-2018	H2020-EU.3.4.						Y
InnoMarket	Innovation in the road freight transportation chain facilitating sustainability and low cost: A socio-technical perspective on work and development of road freight transport markets.	2015-2017	H2020-EU.1.3.					Y	
inteGRIDy	integrated Smart GRID Cross-Functional Solutions for Optimized Synergetic Energy Distribution, Utilization Storage Technologies	2015-2019	H2020-EU.3.4.	Y					

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
IntelHeat	Intelligent control system for railway points heating with supreme saving of electricity	2017-2018	H2020-EU.3.4.						Y
INTERACTION	INnovative TEchnologies and Researches for a new Airport Concept towards Turnaround coordinatION	2013-2016	FP7-TRANSPORT				Y		
INTRANSYS	Delivering next generation Transport Management System to European transport SMEs	2018-2019	H2020-EU.3.4.	Y					
INTRANSYS 2	Delivering next generation Transport Management System to European transport SMEs (2)	2012-2014	H2020-EU.3.4.	Y					
InTraRegio	Towards an Intermodal Transport Network through innovative research-driven clusters in Regions of organised and competitive knowledge	2012-2014	FP7-RoK			Y			
INTUIT	Interactive Toolset for Understanding Trade-offs in ATM Performance	2016-2018	H2020-EU.3.4.		Y				
ISO-COLD	Integrated SOlution to enhance COLD chain and logistic tracking	2015-2015	H2020-EU.3.4.					Y	
IT2RAIL	Information Technologies for Shift to Rail	2015-2017	H2020-EU.3.4.			Y			

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
iTractor	Smart farmer's assistant - iTractor ®	2016-2016	H2020-EU.3.4.						Y
ITS OBSERVATORY	ITS Observatory	2015-2017	H2020-EU.3.4.			Y			
JUPITER	Joint EUropean Project for International ITS/EGNSS awareness Raising	2015-2016	H2020-EU.2.1.						Y
KLIMATOR RSI	A new road status information system for a smarter mobility thanks to an effective and sustainable winter Road Maintenance	2017-2019	H2020-EU.3.4.	Y					
LEDVAR-Z	A New Paradigm for Efficient and Modern Rail Signalling	2016-2018	H2020-EU.3.4.	Y					
LeMO	Leveraging Big Data to Manage Transport Operations	2017-2017	H2020-EU.3.4.	Y					
LessThanWagonLoad	Development of Less than Wagon Load transport solutions in the Antwerp Chemical cluster	2017-2020	H2020-EU.3.4.					Y	
LETS DOHOP	Leveraging the Environment of civil air TranSport with DOHOP	2017-2017	H2020-EU.3.4.		Y				
LOCAL4GLOBAL	SYSTEM-OF-SYSTEMS THAT ACT LOCALLY FOR OPTIMIZING GLOBALLY	2016-2018	FP7-ICT	Y					

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
LOGAM	Low cost GNSS attitude and navigation system with inertial MEMS aiding	2012-2014	FP7-TRANSPORT						Y
LOGICON	Lean Secure and Reliable Logistic Connectivity for SMEs	2013-2015	FP7-TRANSPORT					Y	
LOGIMATIC	Tight integration of EGNSS and on-board sensors for port vehicle automation	2016-2019	H2020-EU.2.1.						Y
LOGINN	LOGistics INNovation uptake	2012-2015	FP7-TRANSPORT					Y	
LOGISTAR	Enhanced data management techniques for real time logistics planning and scheduling	2018-2021	H2020-EU.3.4.					Y	
LowCostTracking	Low cost tracking and data management solution for biopharma cold chain logistics	2016-2016	H2020-EU.3.4.					Y	
MAGYCO	Mems based Appliance for GYro Compassing in general aviation and unmanned aircraft applications	2017-2017	H2020-EU.3.4.						Y
MALORCA	Machine Learning of Speech Recognition Models for Controller Assistance	2016-2018	H2020-EU.3.4.		Y				
MARATHON2OPERATION - M2O	MAke RAil The HOpe for protecting Nature 2 future OPERATION	2018-2020	Shift2Rail - Shift2Rail						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
MARVIN	Independent Smart Machine-Vision Based Cargo Counting Module	2015-2015	H2020-EU.3.4.						Y
MEDIATOR	MEdiating between Driver and Intelligent Automated Transport systems on Our Roads	2018-2021	H2020-EU.3.4.	Y					
MERLIN	Sustainable and intelligent management of energy for smarter railway systems in Europe: an integrated optimisation approach	2016-2018	FP7-SST	Y					
META-CDM	Multimodal, Efficient Transportation in Airports and Collaborative Decision Making	2012-2014	FP7-TRANSPORT			Y			
METROPOLIS	Metropolis, Urban Airspace Design	2013-2015	FP7-TRANSPORT				Y		
MFDS	Multi-Functional Detective System (MFDS) Advanced, Intelligent Transport System creating smarter and safer European roads	2017-2017	H2020-EU.3.4.						Y
MIDAS	Modular and Integrated Digital Probe for SAT Aircraft Air Data System	2018-2021	H2020-EU.3.4.		Y				
MINIMA	MItigating Negative Impacts of Monitoring high levels of Automation	2016-2018	H2020-EU.3.4.		Y				

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
MiniMo-Logistics	MiniMo-Logistics application	2016-2016	H2020-EU.3.4.					Y	
MISTRAL	Communication Systems for Next-generation Railways	2017-2020	H2020-EU.3.4.	Y					
MITIGATE	Multidimensional, integrated, risk assessment framework and dynamic, collaborative Risk Management tools for critical information infrastructures	2015-2018	H2020-EU.3.4.						Y
MOBIS	Personalized Mobility Services for Energy Efficiency and Security through Advanced Artificial Intelligence Techniques	2012-2015	FP7-ICT						Y
MODULUSHCA	Modular Logistics Units in Shared Co-modal Networks	2012-2016	FP7-TRANSPORT			Y		Y	
MoNIfly	Mobile-Network Infrastructure for Cooperative Surveillance of low flying drones	2017-2020	H2020-EU.3.4.		Y				
MOPED	Mobility Optimisation: Permits for Emissions from Driving	2016-2018	FP7-PEOPLE	Y					
MOTO	the embodied reMOte Tower	2016-2018	H2020-EU.3.4.		Y				
MOVINGRAIL	MOving block and VIrtual coupling New Generations of RAIL signalling	2018-2020	Shift2Rail						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
MUGICLOUD	PLUG AND PLAY intelligent transport system for bus and coach sector	2016-2018	H2020-EU.3.4.	Y					
MUPIA	Manufacturing process for ultimate performance inertial MEMS Gyroscope (MUPIA)	2018-2020	H2020-EU.3.4.						Y
NAVDEC	Navigational Decision Support System for Improved COLREGs Safety Management	2015-2015	H2020-EU.3.4.						Y
NAVISAS	Navigation of Airborne Vehicle with Integrated Space and Atomic Signals	2016-2017	H2020-EU.3.4.						Y
NEWS	Development of a Next generation European Inland Waterway Ship and logistics system	2013-2015	FP7-SST					Y	
NEXTRUST	Building sustainable logistics through trusted collaborative networks across the entire supply chain	2015-2018	H2020-EU.3.4.					Y	
NGTC	Next Generation Train Control	2016-2018	FP7-TRANSPORT	Y					
NICENAV	Navigation-grade ITAR-free Certifiable Equipment for the Navigation of Air Vehicle, based on FOG technology	2016-2017	H2020-EU.3.4.						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
NICENAV	NICENAV Navigation-grade ITAR-free Certifiable Equipment for the Navigation of manned and unmanned Air Vehicle, based on FOG technology	2015-2015	H2020-EU.3.4.						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	
OMNISCIENT	Prediction and optimisation platform for the mobile assets management	2018-2018	H2020-EU.3.4.					Y	
OptiFrame	An Optimization Framework for Trajectory Based Operations	2016-2018	H2020-EU.3.4.		Y				
OptiYard	Optimised Real-time Yard and Network Management	2017-2019	H2020-EU.3.4.					Y	
PACAS	Participatory Architectural Change Management in ATM Systems	2016-2018	H2020-EU.3.4.		Y				
Park4SUMP	Actions demonstrate how Park4SUMP will lead to achieve sustainable transport in urban areas by strategically integrating innovative parking management solutions into SUMP policies.	2018-2022	H2020-EU.3.4.				Y		
PARTAKE	cooPerative depArtuRes for a compeTitive ATM networK sErvice.	2016-2018	H2020-EU.3.4.		Y				

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
PASSME	Personalised Airport Systems for Seamless Mobility and Experience	2015-2018	H2020-EU.3.4.				Y		
PERF-AI	Enhance aircraft performance and optimisation through utilisation of artificial intelligence	2018-2020	H2020-EU.3.4.		Y				
PICASSO	Preventing Incident and Accident by Safer Ships on the Oceans	2016-2018	CEF					Y	
PINTA2	IP1 Traction TDI and Brakes TD5 - Phase 2	2016-2018	Shift2Rail	Y					
PIXEL	Port IoT for Environmental Leverage	2018-2021	H2020-EU.3.4.				Y		
PJ01 EAD	Enhanced Arrivals and Departures	2016-2019	H2020-EU.3.4.		Y				
PJ02 EARTH	Increased Runway and Airport Throughput	2016-2019	H2020-EU.3.4.				Y		
PJ03a SUMO	Integrated Surface Management	2016-2019	H2020-EU.3.4.						Y
PJ03b SAFE	Airport Safety Nets	2016-2019	H2020-EU.3.4.				Y		
PJ04 TAM	Total Airport Management	2016-2019	H2020-EU.3.4.				Y		
PJ05 Remote Tower	Remote Tower for Multiple Airports	2016-2019	H2020-EU.3.4.				Y		

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PJ06 ToBeFREE	Trajectory based Free Routing	2016-2019	H2020-EU.3.4.		Y				
PJ07 OAUO	PJ07 Optimised Airspace Users Operations	2016-2019	H2020-EU.3.4.		Y				
PJ08 AAM	Advanced Airspace Management	2016-2019	H2020-EU.3.4.		Y				
PJ09 DCB	Advanced DCB	2016-2019	H2020-EU.3.4.		Y				
PJ10 PROSA	Controller Tools and Team Organisation for the Provision of Separation in Air Traffic Management	2016-2019	H2020-EU.3.4.		Y				
PJ11 CAPITO	Enhanced Air and Ground Safety Nets	2016-2019	H2020-EU.3.4.		Y				
PJ14 EECNS	Essential and Efficient Communication Navigation and Surveillance Integrated System	2016-2019	H2020-EU.3.4.						Y
PJ15 COSER	Common Services	2016-2019	H2020-EU.3.4.		Y				
PJ16 CWP HMI	Controller Working Position / Human Machine Interface - CWP/HMI	2016-2019	H2020-EU.3.4.		Y				
PJ17 SWIM-TI	SWIM Technical Infrastructure	2016-2019	H2020-EU.3.4.		Y				

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PJ18 4DTM	4D Trajectory Management	2016-2019	H2020-EU.3.4.		Y				
PJ19 CI	Content Integration	2016-2019	H2020-EU.3.4.		Y				
PJ20 AMPLE	Master Plan Maintenance	2016-2019	H2020-EU.3.4.		Y				
PJ22 SEabird	PJ22:Validation and Demonstration Engineering	2016-2019	H2020-EU.3.4.		Y				
PJ24 NCM	PJ24 VLD Network Collaborative Management	2016-2019	H2020-EU.3.4.		Y				
PJ25 XSTREAM	Cross Border SESAR Trials for Enhanced Arrival Management	2017-2019	H2020-EU.3.4.				Y		
PJ27 IOPVLD	Flight Object Interoperability VLD Demonstration	2016-2019	H2020-EU.3.4.		Y				
PJ28 IAO	Integrated Airport Operations	2016-2019	H2020-EU.3.4.				Y		
PJ31 DIGITS	Initial Trajectory Information Sharing	2016-2019	H2020-EU.3.4.		Y				
PLASA	Smart Planning and Safety for a safer and more robust European railway sector	2018-2020	H2020-EU.3.4.	Y					
PNOWWA	Probabilistic Nowcasting of Winter Weather for Airports	2016-2018	H2020-EU.3.4.				Y		

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PODIUM	Proving Operations of Drones with Initial UTM Management	2018-2019	H2020-EU.3.4.						Y
PortForward	Towards a green and sustainable ecosystem for the EU Port of the Future	2018-2021	H2020-EU.3.4.				Y		
POSSUM	POsition-based ServiceS for Utilities Maintenance teams	2012-2014	FP7-TRANSPORT						Y
PrEDICTS	Optimizing Container Load for Parcel and Pallet Transport Networks	2018-2018	H2020-EU.2.3.					Y	
PREMISE	PRs receivers with Embedded hardware Intrinsic Security Enhancements	2012-2014	FP7-TRANSPORT						Y
PROMERC	Protection Measures for Merchant Ships	2014-2016	FP7-SECURITY					Y	
Prominent	Promoting Innovation in the Inland Waterways Transport Sector	2015-2018	H2020-EU.3.4.					Y	
PROSPERO	PROactive Safety PERformance for Operations	2012-2015	FP7-TRANSPORT		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	

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PULSARPLANE	PulsarPlane: Worldwide Air Transport Operations	2013-2015	FP7-TRANSPORT						Y
QualiSaR	Development of a Qualification Procedure for the Usage of Galileo Satellite Receivers for Safety Relevant Applications	2012-2014	FP7-TRANSPORT						Y
RADOME	SPHERICAL MULTILAYER RADAR DOME	2016-2016	H2020-EU.3.4.						Y
RANGER	RAdars for loNG distance maritime surveillancE and SaR opeRations	2016-2019	H2020-EU.3.7.						Y
RESILIENCE2050.EU	New Design Principles Fostering Safety, Agility and Resilience for ATM	2012-2015	FP7-TRANSPORT		Y				
RETINA	Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision	2016-2018	H2020-EU.3.4.				Y		
ROPOD	Ultra-flat, ultra-flexible, cost-effective robotic pods for handling legacy in logistics	2017-2020	H2020-EU.2.1.					Y	
RPS	Disruptive Radar Positioning System for trains	2018-2018	H2020-EU.2.1.						Y
R-WAKE	Wake Vortex simulation and analysis to enhance en-route separation management in Europe	2016-2018	H2020-EU.3.4.		Y				

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SAFE-CTS	Efficient and cost-effective intermodal road-rail container freight system	2015-2017	H2020-EU.3.4.			Y			
SAFEDRONE	Activities on drone integration and demonstration in VLL operations	2018-2020	H2020-EU.3.4.		Y				
SaferAfrica	Innovating dialogue and problems appraisal for a safer Africa	2016-2019	H2020-EU.3.4.	Y					
SALSA	SATELLITE-BASED ADS-B FOR LOWER SEPARATION-MINIMA APPLICATION (SALSA)	2016-2018	H2020-EU.3.4.						Y
SAPIENT	Satcom and terrestrial architectures improving performance, security and safety in ATM	2016-2017	H2020-EU.3.4.		Y				
SAT GAM 2018	Small Air Transport (SAT) - GAM 2018	2018-2018	H2020-EU.3.4.		Y				
SATLOC	Satellite based operation and management of local low traffic lines (SATLOC)	2012-2014	FP7-TRANSPORT						Y
S-CODE	Switch and Crossing Optimal Design and Evaluation	2016-2019	H2020-EU.3.4.	Y					
SCOOP@F Part 2	SCOOP@F Part 2	2016-2019	CEF	Y					

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
SEAHUB	Real-time Fleet Performance Center (FPC) to optimize energy efficiency in Maritime Transport to reduce fuel consumption and harmful emissions	2016-2017	H2020-EU.3.4.					Y	
SECOPS	An Integrated Security Concept for Drone Operations	2017-2019	H2020-EU.3.4.		Y				
SECRET	SECurity of Railways against Electromagnetic aTtacks	2012-2015	FP7-SECURITY						Y
SEDNA	Safe maritime operations under extreme conditions: the Arctic case	2017-2020	H2020-EU.3.4.					Y	
SELIS	Towards a Shared European Logistics Intelligent Information Space	2016-2019	H2020-EU.3.4.					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	2016-2019	H2020-EU.3.4.	Y					
SIADE	Spatial Decision Support System for Transportation Planning	2016-2019	H2020-EU.3.4.	Y					
SIADE SaaS	SIADE SaaS: Spatial Decision Support System for Transportation Planning	2017-2019	H2020-EU.3.4.			Y			

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SIMPLI-CITY	SIMPLI-CITY The Road User Information System of the Future	2016-2019	FP7-ICT	Y					
SINSIN	Enhanced PLB, EGNSS receiver, and MEOLUT, according but beyond the standard, significantly improving the localization in difficult conditions, paving the way to a mass market SAR/Galileo service	2017-2020	H2020-EU.3.4.						Y
SISSDEN	Secure Information Sharing Sensor Delivery event Network	2016-2019	H2020-EU.3.7.						Y
Skylynx	Upgrading Railways from the Air	2017-2017	H2020-EU.3.4.						Y
SMApp	SMART MOBILITY APPLICATION TO IMPROVE TRAFFIC MANAGEMENT AND PLANNING	2016-2019	H2020-EU.3.4.	Y					
SMARTER	Surveillance of Maritime Surroundings through Laser Technology	2015-2015	H2020-EU.3.4.						Y
SMARTER TOGETHER	Smart and Inclusive Solutions for a Better Life in Urban Districts	2016-2019	H2020-EU.3.4.	Y					
SmartLog	Smart Logistics and Freight Villages Initiative	2016-2019	H2020-EU.3.4.					Y	
Smart-Rail	Smart Supply Chain Oriented Rail Freight Services - Smart-Rail	2015-2018	H2020-EU.3.4.					Y	

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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
SoCool@EU	Sustainable Organisation between Clusters Of Optimised Logistics @ Europe	2012-2014	FP7-REGIONS					Y	
SOCRATES 2.0	System of Coordinated Roadside and Automotive Services for Traffic Efficiency and Safety	2016-2019	CEF Transport	Y					
SPLASH	Sail PLAn service for energy efficient SHipping (SPLASH) - innovative and revolutionary sail planning	2016-2017	H2020-EU.3.4.					Y	
SPRINT	Semantics for PerfoRmant and scalable INteroperability of multimodal Transport	2018-2020	Shift2Rail			Y			
ST4RT	Semantic Transformations for Rail Transportation	2016-2018	H2020-EU.3.4.			Y			
STM Validation Project	STM Validation Project	2016-2019	CEF	Y					
STRATOFLY	Stratospheric Flying Opportunities for High-Speed Propulsion Concepts	2018-2020	H2020-EU.3.4.		Y				

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
STRESS	Human Performance neurometricS Toolbox foR highly automatEd Systems deSign	2016-2018	H2020-EU.3.4.		Y				
SUCCESS	Sustainable Urban Consolidation CentrES for conStruction	2015-2018	H2020-EU.3.4.					Y	
SUNRISE	Strengthening User Networks for Requirement Investigation and Supporting Entrepreneurship	2012-2015	FP7-TRANSPORT						Y
SYNCHRO-NET	Synchro-modal Supply Chain Eco-Net	2015-2018	H2020-EU.3.4.					Y	
TaCo	Take Control	2016-2018	H2020-EU.3.4.				Y		
TACOT	TRUSTED MULTI APPLICATION RECEIVER FOR TRUCKS	2012-2014	FP7-TRANSPORT					Y	
TAXISAT	A new TAXI application guided by SATellite	2012-2014	FP7-TRANSPORT						Y
TBO-MET	Meteorological Uncertainty Management for Trajectory Based Operations	2016-2018	H2020-EU.3.4.		Y				
TELLISYS	Intelligent Transport System for Innovative Intermodal Freight Transport	2012-2015	FP7-TRANSPORT					Y	
TERRA	Technological European Research for RPAS in ATM	2017-2019	H2020-EU.3.4.						Y

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TIMON	Enhanced real time services for an optimized multimodal mobility relying on cooperative networks and open data	2015-2018	H2020-EU.3.4.			Y			
TM Academy	TM Academy - intelligent transport control and monitoring system	2016-2019	H2020-EU.3.4.	Y					
TrafficFlow	TrafficFlow - Analytics for Smarter Cities	2016-2019	H2020-EU.3.4.	Y					
TrafficWise	Transforming Cellular Network Data Into the Next Generation of Mobility Management Platform	2016-2019	H2020-EU.3.4.	Y					
TransAID	Transition Areas for Infrastructure-Assisted Driving	2016-2019	Horizon2020	Y					
TransSec	Autonomous emergency manoeuvring and movement monitoring for road transport security	2018-2021	H2020-EU.3.4.					Y	
TripOD	Advanced Analytics for Trip Origin-Destination Matrices	2016-2019	H2020-EU.3.4.	Y					
TRUST	TRUck Suistanable Transport - Innovative project for management of Contract Logistics	2017-2017	H2020-EU.3.4.					Y	
UPP	STPRMS - Sustainable Truck Parking Reservation Management System	2015-2016	H2020-EU.3.4.				Y		

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UrbanDynamics	Changing the world of urban mobility thanks to Computer Vision and Artificial Intelligence	2016-2019	H2020-EU.2.3.	Y					
VDRConnect	VDRConnect: VDR-based vessel telematics solution	2016-2016	H2020-EU.3.4.					Y	
VISION	Validation of Integrated Safety-enhanced Intelligent flight cONtrol	2016-2019	H2020-EU.3.4.						Y
Vista	Market forces trade-offs impacting European ATM performance	2016-2018	H2020-EU.3.4.		Y				
VIWAS	Viable Waggonload production Schemes	2012-2015	FP7-TRANSPORT			Y			
VOICI	Solutions for voice interaction towards natural crew assistant	2018-2019	H2020-EU.3.4.		Y				
Watertruck+	Watertruck+	2014-2019	CEF					Y	
WeShare	Innovative Platform for horizontal collaboration in Road freight transportation	2018-2018	H2020-EU.2.3.					Y	
X2RAIL 3	Advanced signalling, Automation and Communication System (IP2 and IP5) - Prototyping the future by means of capacity increase, autonomy and flexible communication	2018-2021	Shift2Rail						Y

Acronym	Project name	Project duration	Source of funding	Traffic Management Systems	Air Traffic Management	Intermodal Management Systems	Travel Hub Management	Freight Transport and Logistics	Sensors and Detection Systems
X2Rail-1	Start-up activities for Advanced Signalling and Automation Systems	2016-2019	H2020-EU.3.4.						Y
X2RAIL-2	Enhancing railway signalling systems based on train satellite positioning, on-board safe train integrity, formal methods approach and standard interfaces, enhancing Traffic Management System functions	2016-2019	H2020-EU.3.4.	Y					

Annex 2: Scopus database regular expression analysis keywords

REGEX keywords (documents retrieved on November 2019):

Intelligent transport systems

TITLE-ABS-KEY("intelligent transportation system") OR TITLE-ABS-KEY("intelligent transport system") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

Traffic management systems

TITLE-ABS-KEY("rail traffic management") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

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

TITLE-ABS-KEY("gsm-r") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

TITLE-ABS-KEY("road traffic management") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

TITLE-ABS-KEY("vessel traffic services") AND TITLE-ABS-KEY("vessel traffic management") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

TITLE-ABS-KEY("air traffic management") AND (PUBYEAR > 2009) AND (PUBYEAR < 2020)

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