ISSN 1831-9424

European Commission

JRC SCIENCE FOR POLICY REPORT

Research and Innovation in Urban Mobility and Logistics in Europe

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

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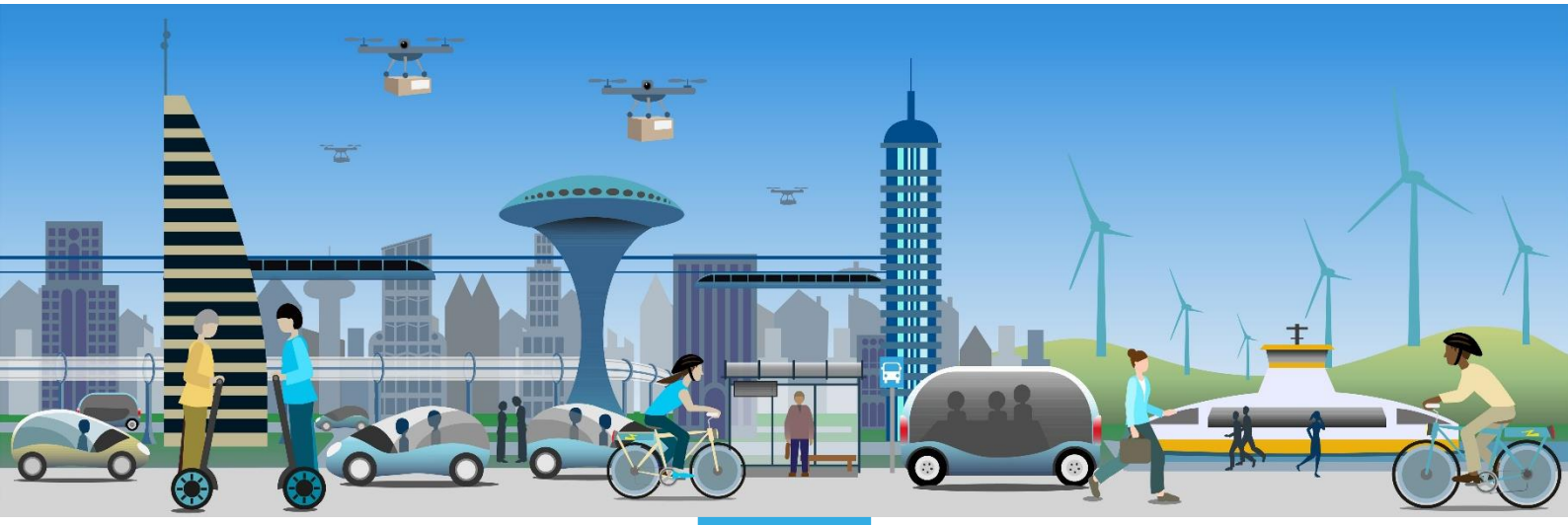
2022



Joint Research Centre

EUR 31197 EN

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EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC130426

EUR 31197 EN

Print	ISBN 978-92-76-56340-2	ISSN 1018-5593	doi:10.2760/40068	KJ-NA-31-197-EN-C
PDF	ISBN 978-92-76-56341-9	ISSN 1831-9424	doi:10.2760/32604	KJ-NA-31-197-EN-N

Luxembourg: Publications Office of the European Union, 2022

How to cite this report: Gkoumas, K., Stepniak, M., Cheimariotis, I., Marques dos Santos, F., Grosso, M., and Pekár, F., *Research and Innovation in Urban Mobility and Logistics in Europe — An assessment based on the Transport Research and Innovation Monitoring and Information System (TRIMIS)*, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/32604, JRC130426.

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Abstract

The European Green Deal and its target to achieve a 90% reduction in transport-related greenhouse gas emissions by 2050 together with the new EU Urban Mobility Framework put urban mobility and logistics in the spotlight of EU mobility policies. Research and innovation is paramount to respond to the challenges and to further improve mobility and transport systems in cities, while fully tackling the negative impacts of transport. This report provides a review of recent trends, challenges and achievements of European research and innovation initiatives in urban mobility and logistics. The report identifies relevant projects that focus on urban mobility, using the Transport Research and Innovation Monitoring and Information System (TRIMIS) database. It identifies the main trends in European research and it discusses main areas of development and key achievements. It also presents recommendations for future research priorities and initiatives.

Acknowledgements

The Joint Research Centre is in charge of the development of the Transport Research and Innovation Monitoring and Information System (TRIMIS), and the work has been carried out under the supervision of the Directorate-General for Mobility and Transport (DG MOVE) and the Directorate-General for Research and Innovation (DG RTD) that are co-leading the Strategic Transport Research and Innovation Agenda (STRIA). The authors would also like to acknowledge the input and review of Paola Chiarini, Ines Hartwig, Piotr Rapacz, Robert Szucs and Isabelle Vandoorne at DG MOVE and Octavia Stepan at CINEA, and the support given by Ricardo-AEA Ltd. to TRIMIS. The views expressed here are those of the authors and may not, under any circumstances, be regarded as an official position of the European Commission.

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Executive summary

The report presents an analysis of research and innovation in urban mobility and logistics in Europe. The report assesses European Union projects mostly funded under the Horizon 2020 (H2020) Framework Programme since 2014. It uses the Transport Research and Innovation Monitoring and Information System (TRIMIS) database to identify relevant projects which have urban mobility and logistics in their scope. The report provides a review of recent trends, challenges and achievements of European research and innovation initiatives in urban mobility and logistics and provides recommendations on future priorities.

Policy context

The European Green Deal has set a very ambitious target of emissions reduction, which is anticipated to have a considerable impact on mobility and transport. The goal of the EU Sustainable and Smart Mobility Strategy is, among others, to ensure modal shift towards more sustainable transport modes, namely public transport and active modes. In order to achieve that, European urban areas need modern, green, inclusive, and more resilient EU transport. Finally, the new European Urban Mobility Framework (UMF), published in 2021, emphasises the importance of public transport, active mobility options and efficient zero-emission urban logistics and last mile delivery, as well as the need for more effective sustainable urban mobility planning and urban mobility data.

Key conclusions

The quantitative and qualitative analysis of projects relevant to urban mobility and logistics identified the main actors, trends and achievements. Key conclusions are:

- 331 projects have been identified as relevant to urban mobility and logistics R&I in Europe; these projects cover to a large extent the ambitions of the new EU Urban Mobility Framework.
- The research and innovation effort in H2020 is in line with the most important challenges set out in the UMF;
- On the way forward for R&I:
    - Supporting cities on data collection and guidance on calculating sustainable urban mobility indicators in order to increase the evidence base for SUMP planning and implementation will be very important.
    - Further initiatives should concentrate on positioning active and micromobility in transport and urban planning, highlight their role in multimodal trips and transport-related climate emissions, and cover technical as well as regulatory needs. The safety of vulnerable road users remains one of the main concerns. Citizens can and are willing to take an active role in co-creating sustainable mobility solutions.
    - Identification, harmonisation and standardisation of best practises in pilot programmes across all projects is important for their take up, scale-up and diffusion. This can be further promoted by making projections of what sustainability and economic benefits for cities and stakeholders can be expected in the future when these best practices in urban mobility and freight logistics will be implemented in full scale.
    - Conducted works on intermodal connection between long-distance and last-mile freight logistics in Trans-European Transport Network (TEN-T) urban nodes are essential but the topic still needs to be further investigated.
    - Future research and innovation initiatives should also concentrate on fostering the early adoption of new mobility concepts (such as autonomous vehicles and Urban Air Mobility (UAM)) in Sustainable Urban Mobility Plans (SUMPs), for which little provision is currently included.
    - With the technologies reaching higher maturity, the challenge for UAM will be to integrate them into operational aspects and further test autonomous flight capabilities in a staged approach in real life conditions. Beyond that, public engagement and co-creation are important tools to be developed and considered for the acceptance of new technologies, especially as the latter are brought into more mature phases.
    - Future studies should also consider user perspectives and preferences related to electric vehicles (EVs) and their charging.

- The EU Climate-neutral and Smart Cities mission provides the opportunity to scale up, demonstrate in real environments and pilot with real cities the technologies already developed in R&I projects, while technological advances on their own will not be sufficient to reduce transport-related climate emissions in urban areas.

Main findings

Main findings are reported below for the seven action areas of the UMF investigated in this report. The area of attractive public transport services was covered in a recent TRIMIS report on Public Transport R&I in Europe (Stepniak et al. 2022).

1. A reinforced approach to TEN-T urban nodes

The proposed revision of the TEN-T regulation, in alignment with the EU Urban Mobility Framework underlines the importance of multimodal urban nodes. The conducted works on intermodal connection between long-distance and last-mile freight logistics are essential but the topic still needs to be further investigated. The recently started projects address governance of multimodal zero emission mobility hubs for passengers and freight. However, those solutions need to be further embedded into a broader urban transport planning perspective and they would likely require further technological advances.

2. A reinforced approach to SUMPs and mobility management plans

The concept of SUMPs emerged in the EU urban transport policy in 2013 and since then it has been incorporated in EU funded research. The projects assessed in this report focus on many aspects that can help public authorities design SUMPs, from development of models and software tools to cross-stakeholder collaboration actions. The projects also introduce new technological developments into SUMPs and avail from Big Data analytics capacities. On urban freight transport and logistics, research efforts embrace the concept of Sustainable Urban Logistics Plans (SULPs) which followed the introduction of SUMPs. While SUMPs (and, to a lesser extent, SULPs) are a mature concept, their uptake is still ongoing and subject to national differences as well as barriers and disruptions (for example the COVID-19 crisis). Continuous effort and support for local authorities is necessary for their implementation, monitoring as well as refinement and adaptation. A sustained effort is needed to centralise, harmonise and analyse the wealth of information and experience from previous projects, and rationalise the tools and guidelines**.** Future research should focus on the early adoption of new mobility concepts (such as Cooperative, Connected and Autonomous Mobility - CCAM and UAM), for which little R&I is currently dedicated. A staged approach for introducing new concepts considering their development timeline could be necessary. Along with Living Labs, it is expected that modern transport modelling approaches and simulations (e.g. digital twins and agent-based modelling) will be used to simulate solutions and project their large scale benefits and trade-offs. Mobility management plans are proposed as a means to change attitudes and travel behaviour with the ultimate goal to create a new mobility culture, for example for companies to get employees to travel to work using sustainable modes of transport. Even if certain projects engage with mobility management plans, few examples of successful deployment are reported up to now, therefore there is potential and need for their further deployment and evaluation.

3. Monitoring progress – sustainable urban mobility indicators

For that reason, a pilot project defined and tested a set of 18 relevant indicators, covering the defined core areas of (i) road safety, (ii) access to public transport, (iii) GHG emissions, and, (iv) air quality, and provided a relevant benchmarking tool. The pilot covered indicators for 46 cooperating cities. Further works are necessary for a widespread use of the tool among all European cities as it provides a common approach to monitoring and data collection. Current research supports cities in data collection and guidance on indicator calculations, and sets up an observatory at EU level.

4. Healthier and safer mobility – a renewed focus on walking, cycling and micromobility

The Urban Mobility Framework puts emphasis on making active mobility more popular, safer and better embedded into urban transport planning. Previous European research and innovation projects have achieved positive results related to active mobility promotion and collecting good practices in different urban settings (e.g., commuting to work and to school, tourist destinations etc.). Active mobility and micromobility are part of the guidelines and recommendations in transport planning, however few studies show the role of active modes in multimodal trips and thus further work is necessary. The safety of vulnerable road users, cyclists or users of micromobility vehicles remains one of the main concerns. Although some technological R&I has already been carried out in the field (e.g., sensor-based detection systems), the safe-system approach at the level of the whole city transport infrastructure appears to have more potential in increasing safety of active mobility. With

the anticipated uptake of active modes, safety practices should be scaled up accordingly and further R&I effort is needed to cover technical as well regulatory, planning and monitoring needs. In particular, a common EU approach on regulation regarding the safety of micromobility users is probably necessary, including guidance for local and / or national authorities on its implementation. Certain R&I projects examine the direct health benefits for active mobility users, and the indirect health benefits for the urban population through congestion and pollution reduction, and advocate for their integration in the planning process, and even attempt to estimate them and convert them into financial savings for the healthcare system. This R&I area has further potential for investigation, refinement and dissemination. Finally, promoting citizen engagement and co-creation is particularly appropriate and effective in promoting sustainable and active mobility at the neighbourhood level, as this directly affects their quality of life.

5. Zero-emission city freight logistics and last-mile delivery

Urban freight transport and logistics are, as urban mobility in general, in a process of profound transformation, driven by the following drivers. First, the on-demand economy and e-commerce has boomed, boosting urban economic activity even during COVID-19 propagation mitigation and associated restrictions in mobility. This has increased the need for freight throughput, increasing the strain on existing urban networks and systems. Second, in response to the sustainability objectives put forward by the European Commission, and the policies, regulations and guidelines stemming out of these objectives, urban freight must cut its environmental footprint, diversify its energy resources, thus contribute also to its resilience. Finally, for further European transport integration according to the TEN-T corridor paradigm, urban freight has to contribute to the efficient integration of urban nodes in the network by promoting seamless multimodal flows. These strong drivers require a holistic approach, including but not limited to technology developments. The systemic complexity of operations and the diversity of actors involved, require an ever-increasing effort in collaboration as well as observation and knowledge management. Finally, since several, past and present, projects share similar ambitions, it is desirable to promote further harmonisation, coordination, standardisation and sharing of best practices. It would also appear beneficial to estimate and bring forward the environmental, societal and economic benefits of best practices when scaled up and widely adopted.

6. Digitalisation, innovation and new mobility services

For CCAM in the urban environment, safety is a priority, especially when there is mixed traffic, and where autonomous road vehicles must take into account a diverse array of scenarios. There is substantial research on Mobility as a Service (MaaS), with many concepts validated in Living Labs and real cases. Although an overlap in research in high maturity pilot projects can be observed, this is beneficial, since the complexity of the different environments leads to distinct conclusions and additional insights on challenges towards deployment. Similar to car-pooling and shared mobility, research is expected to continue availing from the recent developments in ICT technologies and the increase of Big Data analytics capacity. In fact, ICT provides the backbone for future research: from data collection, online optimisation of traffic flows and coordination between stakeholders, to benchmarking and monitoring the systems' operation. For multimodal mobility, seamless integration of the ICT platforms of different modes, including information exchange between them, is critical for the development of applications that allow for optimal trip planning. For UAM, there is substantial research that focuses on the safe integration of UAM in the urban environment. The research spans many challenges, from defining concepts of operations, to intelligent and fail-safe guidance-navigation-control, safe separation of drones, and integration with communications, navigation, and surveillance and air traffic management (ATM) systems. On-going projects plan to test UAM in Living Labs. With the technologies reaching higher maturity, the challenge will be to integrate them into operational aspects and further test autonomous flight capabilities in a staged approach in real life conditions. Urban rail transit is an important component of urban mobility and transport, with research on ICT and on the deployment of automated and semi-automated trains, to bring reliability, increased capacity and reduced costs. Beyond that, public engagement and co-creation are important tools to be developed and considered for acceptance of new technologies, especially as they are brought into more mature phases.

7. Towards climate-neutral cities – resilient, environmentally friendly and energy-efficient urban transport (with a focus on infrastructure for zero emission vehicles)

In the context of the Sustainable and Smart Mobility Strategy, and the EU mission on Climate-Neutral and Smart Cities, a key milestone is to have at least 100 climate-neutral European cities by 2030. Urban mobility is at the heart of this challenge and consequently the Urban Mobility Framework promotes initiatives to facilitate the transition to climate neutrality. To achieve it, urban mobility will require the fusion and upscaling of best practices in all action areas of the UMF, while ensuring synergies with other areas such as renewable energy production and storage. For this reason, some of its objectives are already in the focus of other action areas of the UMF, especially public transport and active mobility as well as the transition to shared mobility services and

connected and automated mobility. One key objective of the action area that still stands out is the need for efficient, interoperable and user-friendly recharging and alternative fuels refuelling infrastructure in urban areas. The previous projects cover a broad range of topics from detailed technological solutions (e.g. fast chargers, charging pads, real-time data for checking availability of charging stations etc.), to grid optimisation or integration of electric vehicles into urban transport systems, and up to new business models. Nevertheless, further works are still necessary to develop and test new solutions as well as to push forward existing ones, in particular to scale them up and reduce installation and operational costs (for both city authorities and individual users). Importantly, future research and innovation initiatives could take advantage of the Climate-neutral and Smart Cities mission, to push forward solutions for achieving climate neutrality, focusing not only technological aspects but also on social issues, policy and regulatory needs, as well as governance and implementation modalities, with the participants from the 100 climate neutral and smart European cities by 2030 serving as the frontrunners.

Related and future JRC work

Since 2017 TRIMIS reports have covered a wide range of transport topics and presented analyses of relevant research and innovation initiatives in Europe, providing recommendations to policy makers on future initiatives. A recently published TRIMIS report focuses on public transport innovation in Europe.

Quick guide

Section 1 provides the context of the report and presents the aims of the analysis and structure of the document. It also describes the research approach and the selection method of relevant projects. Section 2 places the analysis in the wider European policy context. Section 3 provides a visual summary of quantitative trends in recent European research and innovation initiatives. Section 4 presents qualitative assessments of the relevant research and innovation projects, while Section 5 focuses on the main achievements of these projects. The final section 6 concludes with the identification of future research needs and provides policy recommendations.

1 Introduction

The era of the European Green Deal (European Commission, 2019) and its ambitious target for the drastic reduction of transport emissions creates new conditions for urban mobility. The new EU Urban Mobility Framework (European Commission, 2021a) details present and future challenges for cities, putting in the spotlight the importance of sustainable urban mobility planning (SUMP) as a strategic framework which should prioritise public transport, active mobility options and efficient zero-emission urban logistics and last mile delivery.

In order to strengthen existing tools and to complement them with new ones for achieving the ambitious aims of the Framework, a broad spectrum of research and innovation (R&I) efforts is required. The electrification of transport, the implementation of alternative fuels, the development of supporting infrastructure and a shift to more sustainable transport choices, namely public transport and active mobility, are crucial to achieve the desired emissions reduction. Improvement in transport management and implementation of sustainable urban mobility plans (SUMPs) help address the challenges that urban areas face. Urban vehicle access regulations (UVARs) can help alleviate air quality issues caused by transport, and reduce transport-related CO2 emissions and road congestion. Active mobility such as walking and cycling, also as part of multimodal trips, together with micromobility, can help to reduce air pollutants and CO2 emissions, as well as improve the health of users. New digital solutions are essential to further improve quality of service of public transport, making it more attractive, affordable and safer. More efficient and zero-emission urban freight transport and last mile delivery can help lower emissions, alleviate traffic and improve the delivery chain efficiency. All of these should be achieved having in mind a progressing automation of transport and upcoming connected and autonomous vehicles.

The main aim of this report is to analyse main trends, challenges and achievements of European R&I initiatives in urban mobility and logistics, and to give recommendations on the focus of future R&I initiatives. The report uses the Transport Research and Innovation Monitoring and Information System (TRIMIS) database in order to identify all relevant projects which focus on urban mobility and logistics. TRIMIS has been developed by the European Commission's Joint Research Centre (JRC) under the Horizon 2020 Work Programme 2016-2017 on Smart, Green and Integrated transport (European Commission, 2017; Tsakalidis et al. 2020) and continued under the Horizon 2020 Work Programme 2018-2020 (European Commission, 2020a). It is an integrated transport policy-support tool which operates as a knowledge management system offering open-access information about transport-related R&I initiatives in Europe and beyond. TRIMIS collects data on European projects and projects funded from national sources, coming from Member States (MS), associated countries and others.

The report is based on the TRIMIS project database, enriched by projects available from other sources. In this study, we focus on Horizon 2020 Framework Programme for Research and Innovation (H2020) projects which target urban mobility and logistics while in the previous study we covered public transport ([1]). We applied automatic search for projects in the TRIMIS database using pre-selected keywords that focused on: active modes, micromobility, urban rail, last mile delivery, logistics, low emission transport, electromobility, connected and automated mobility, MaaS, urban transformation, inclusive and accessible urban mobility planning and mobility management. In a second step we manually checked and verified the list of projects, in order to ensure the selected ones are relevant to urban mobility.

To enrich the analysis, we identified relevant R&I projects from other sources, and we subsequently added them to TRIMIS. These additional sources include:

- Urban Innovative Actions (UIA) projects – projects from an Initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges. Urban mobility is one of the topics tackled by the initiative and five projects have been financed.
- Interreg projects - Interreg is a cooperation programme that aims to foster cooperation between regions and to tackle the obstacle of national borders within EU and between Member States and neighbouring countries. The main focus of these projects is on improving policy instruments through promotion of interregional learning, gathering and sharing good practices, key recommendations and action plans. It also helps reducing disparities in the levels of development, growth and quality of life in and across Europe's

([1]) https://publications.jrc.ec.europa.eu/repository/handle/JRC129420

regions. All collected good practices, including their detailed factsheets are available via the Interreg platform ([2]).

Once we identified projects, we reviewed them according to their relevance and implementation period. In total, we considered **331 projects**, including projects from SME (Small and Medium Enterprise) financing instruments ([3]), looking at their background, scope and achievements. The dataset with all selected projects is available via the JRC Data Catalogue ([4]). The details of the selection process, embedded in a general overview of the approach of the report, is schematically presented in **Figure 1**.

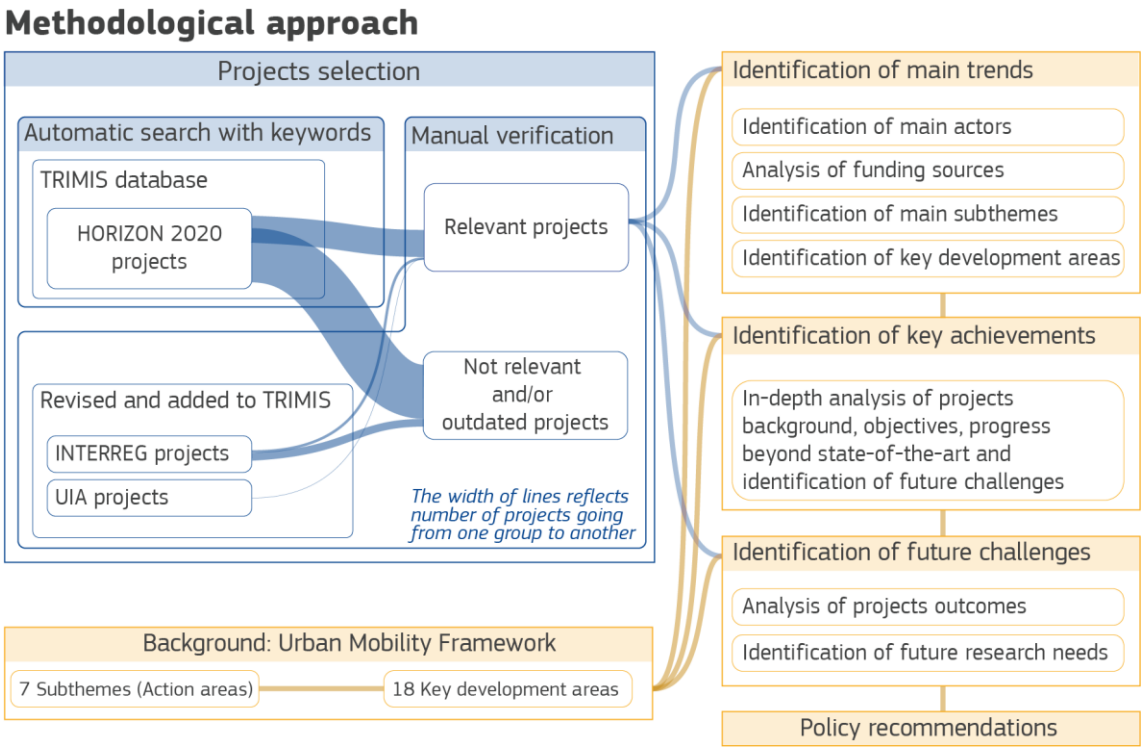
The width of the blue lines reflects the number of projects coming from one group to another. The majority of projects included in the report are H2020 projects automatically derived from the TRIMIS database (**302** out of 331), including CIVITAS projects, followed by additional data sources: 20 Interreg projects and five UIA projects. Note that some of the projects included in the supplementary lists were already identified in the TRIMIS database.

Based on the detailed description of identified projects, in Section 3 we discuss MS involvement and funding sources. Furthermore, we assigned the projects to one or more of the seven identified subthemes derived from seven of the nine action areas of the new EU Urban Mobility Framework (UMF).

Then in Section 4 we present an in-depth analysis of a selection of **133** projects representative of the identified subthemes, their descriptions, and outcomes, in order to identify the main areas of development. We describe them following the same structure: the introduction and problem statement which put the achievement in a broader spectrum, which is followed by performed work and actual achievements in the area. We conclude with identifying potential or future R&I needs.

Finally, we summarise the report focusing on future challenges (Section 5) aiming at providing recommendations on future research initiatives.

Figure 1. Research approach



Source: Own elaboration

([2]) https://www.interregeurope.eu/policy-solutions/good-practices
([3]) https://ec.europa.eu/research/participants/docs/h2020-funding-guide/cross-cutting-issues/sme_en.htm
([4]) Marques dos Santos et al. 2022, http://data.europa.eu/89h/250cc292-efee-4df4-a74d-ec7d84464bea

2 Background and key challenges

2.1 Urban mobility and logistics in the scope of European strategic documents

The 2019 European Green Deal (European Commission, 2019) aims at a 90% reduction in greenhouse gas (GHG) emissions by 2050. Transport currently accounts for a quarter of the EU's GHG emissions, and this figure continues to rise as demand for transport grows and modal shift to the least polluting modes is not taking place sufficiently quickly. Meeting the objective for GHG reduction will require a faster modal shift to low- and zero-emission modes (in particular public transport and active mobility) and an increased uptake of clean vehicles and alternative fuels. Improving public transport, fostering multimodality and investing in active mobility infrastructure is expected to help to drastically reduce pollution especially in cities. In order to support this effort, the Commission established the EU Climate-neutral and Smart Cities Mission which aims to deliver at least one hundred climate-neutral and smart cities in Europe by 2030 (European Commission, 2021b).

The December 2020 'Sustainable and Smart Mobility Strategy' (SSMS) (European Commission, 2020b) and the accompanying action plan of 82 initiatives aims at achieving a modern, green, and more resilient EU transport system. Making interurban and urban mobility healthy and sustainable will help achieve these goals.

The new EU Urban Mobility Framework (UMF) published in December 2021 puts public transport, multimodality, and active and shared mobility in the spotlight while stressing the importance of an effective local transport strategy (sustainable urban mobility plan) and urban mobility data and indicators. The Commission's communication on the new EU Urban Mobility Framework groups the desired actions into nine main blocks (see Box 1 for details).

Box 1. Action areas of the new EU Urban Mobility Framework
1. A reinforced approach to TEN-T urban nodes
2. A reinforced approach to Sustainable Urban Mobility Plans (SUMPs) and mobility management plans
3. Monitoring progress – sustainable urban mobility indicators
4. Attractive public transport services, supported by a multimodal approach and by digitalisation
5. Healthier and safer mobility: a renewed focus on walking, cycling and micromobility
6. Zero-emission city freight logistics and last-mile delivery
7. Digitalisation, innovation and new mobility services
8. Towards climate-neutral cities: resilient, environmentally friendly and energy-efficient urban transport
9. Awareness raising and capacity building

2.2 Areas addressed by this report

This report adopts clustering into subthemes. The subthemes help organise the review process of identified projects and to detect main trends. The subthemes are derived from the action areas of the new UMF:

1. **A reinforced approach to Trans-European Transport Network (TEN-T) urban nodes** including topics such as: multimodal hubs (passenger and freight), park & ride solutions;
2. **A reinforced approach to Sustainable Urban Mobility Plans (SUMPs) and mobility management plans** including urban mobility and logistics planning and management plans, stakeholder involvement, Sustainable Urban Logistic Plans integration;
3. **Monitoring progress – sustainable urban mobility indicators** including initiatives on harmonised mobility indicators, development and implementation of indicator benchmarking tools etc.;
4. **Healthier and safer mobility: a renewed focus on walking, cycling and micromobility** including behavioural change, modal shift towards active modes, micromobility (including electric scooters) and no car solutions, e-bikes and e-cargo bikes, cycling infrastructure, road safety (with the special attention to vulnerable road users), citizen co-creation and sustainable neighbourhood planning;
5. **Zero-emission city freight logistics and last-mile delivery** including development and implementation of Sustainable Urban Logistic Plans, zero-emission freight urban logistics, last-mile delivery, freight urban logistics infrastructure, new distribution models, dynamic routing, and a better multimodal connected use of urban rail and inland waterways;
6. **Digitalisation, innovation and new mobility services** including data collection, harmonisation, analysis, visualisation and reporting, digital twins, artificial intelligence, Connected and automated

mobility, real-time data collection (including traffic information services), urban vehicle access regulations (UVARs), free-floating car and bike sharing, ride hailing and innovative taxi services, Urban Air Mobility, or delivery services together with digital solutions and services, e.g. supportive applications, shared mobility and Mobility as a Service (MaaS) applications;

7. **Towards climate-neutral cities: resilient, environmentally friendly and energy-efficient urban transport** with a specific focus on efficient, interoperable and user-friendly recharging and alternative fuels refuelling infrastructure, clean fuels, electromobility, hydrogen, etc., as other objectives of this action area, such as an increased focus on active mobility, are addressed in the rest of subthemes.

This thematic repartition choice covers urban mobility from different perspectives, first from the policy frameworks' perspective (TEN-T urban nodes, SUMPs and SUMIs), then through identified objectives (healthier and safer mobility, zero emission freight logistics, towards climate neutral cities), and finally digitalisation, innovation and new mobility services which are means and solutions for achieving the objectives. Since the subthemes and perspectives are not mutually exclusive, themes can overlap. In the above list, an effort is made to appropriately account for projects researching more than one action areas of the new UMF, (e.g., Sustainable Urban Logistic Plans integration from subtheme 2 above is relevant also to subtheme 5; likewise, e-cargo bikes in subtheme 4 is also relevant to subtheme 5), however a dominant subtheme choice is often made for practical classification purposes. It is also of note that Digitalisation and ICT, while a subtheme in its own, is a core constituent in a majority of projects and methodological approaches across subthemes.

Two action areas of the UMF are not made part of the list of subthemes:

— **Attractive public transport services, supported by a multimodal approach and by digitalisation** – the topic was covered in a dedicated recent TRIMIS report on Public Transport R&I in Europe (Stepniak et al. 2022).

— **Awareness raising and capacity building** – covering actions of high importance, this thematic area is treated in the projects falling under subthemes 1 & 2 on governance, cooperation and promotion. It is not in its own the focus of funded R&I activities.

2.3 Key challenges in urban mobility and logistics research and innovation

The analysis of the EU urban mobility policy (UMF), complemented by the review of recent R&I projects on urban mobility and logistics enable us to identify the following topics as key areas of R&I:

1. Topics related to a reinforced approach to TEN-T urban nodes
2. Topics related to a reinforced approach to Sustainable Urban Mobility Plans (SUMPs) and mobility management plans
3. Topics related to monitoring progress – sustainable urban mobility indicators
4. Topics related to a healthier and safer mobility: a renewed focus on walking, cycling and micromobility
    - Promoting active mobility for all
    - Technology development for cycling and micromobility
    - Sustainable urban neighbourhoods
5. Topics related to zero-emission city freight logistics and last-mile delivery
6. Topics related to digitalisation, innovation and new mobility services
    - CCAM in urban environment
    - Safe urban mobility
    - Mobility as a Service
    - Shared mobility services
    - Urban Air Mobility
    - Data driven innovative solutions for traffic management
    - Digital tools for transport planning
    - ICT solutions for rail in urban environment

- Innovation in citizen engagement and co-creation of mobility solutions

7. Topics towards climate-neutral cities: resilient, environmentally friendly and energy-efficient urban transport
   - Electric vehicle charging, grid infrastructure and technology
   - Hydrogen in the urban context

3 Overview of European research and innovation

In this section we provide an overview of European research projects in urban mobility and logistics. First, we investigate the involvement of EU MSs in H2020 R&I projects (**Figure 2**), including the type of action which provides funding for projects (**Figure 3**). Finally, we group selected projects into thematic groups in order to identify main thematic areas on which R&I projects have focused (**Figure 4**).

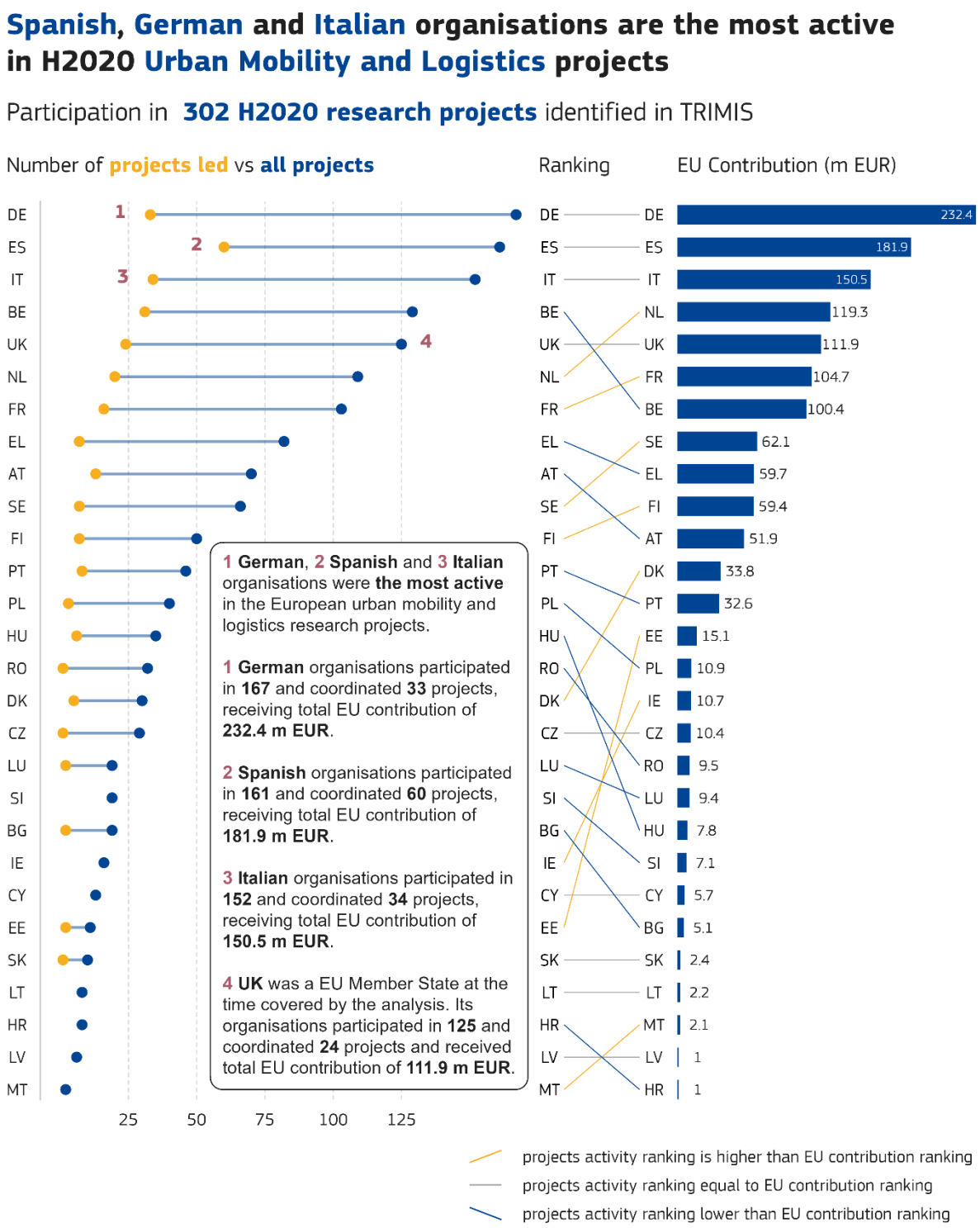
Main takeaways concerning the **participation of Member States in 302 H2020 projects** (**Figure 2**):

- **German organisations are the most active in European R&I urban mobility and logistics projects**, considering the number of projects they participate in (167) and the total EU contribution (EUR 232 million, approximately).
- **Spanish organisations coordinated the highest number of projects** (60). They also participated in 161 projects and they received the second highest total EU contribution (EUR 182 million).
- Italian organisations rank third in terms of project participation (152), coordination (34) and total EU contribution (EUR 150 million); the next are organisations from the UK, France, the Netherlands, and Belgium (over EUR 100 million).
- **Organisations from the three most active countries received almost 37.4% of all European funding** (EUR 564.8 million out of EUR 1511.7 million) directed to the identified H2020 urban mobility related projects. This shows a relatively high concentration of funding in terms of the countries the contribution is directed to.
- The United Kingdom was an EU Member State during most of the time period covered by the analysis. Its organisations participated in 125 and coordinated 24 projects and received a total EU contribution of EUR 111.9 million.
- **All EU27+UK countries have taken part in urban mobility and logistics related R&I projects**, and 21 of them have coordinated such projects. There is also a quite high correlation between the scale of participation and coordination of R&I projects.
- Spanish organisations have led about 37% of projects they participated in, which underlines their leading role in EU-funded urban mobility and logistics R&I initiatives. At the same time, Slovenia, Ireland and Cyprus have not coordinated any, albeit having participated in 19, 16 and 13 projects respectively.

Figure 3 shows the scale of EU contribution (the size of a dot) in the 331 European projects (H2020 together with projects funded by the Connecting Europe Facility (CEF) or the European Regional Development Fund (ERDF), i.e. Interreg and Urban Innovative Actions (UIA)), which started since 2014 and have urban mobility in their scope. The EU contribution in each of the projects is represented by the size of a dot. Each row shows the number of projects funded from a given source, and they are arranged from the highest to the lowest total EU contribution. Main takeaways:

- the **highest total funding** was directed through 64 Innovation Actions (IA) – more than €884.8 million;
- the **highest number of projects** (98) are funded under the Research and Innovation Actions (RIA) funding scheme;
- **there are 11 projects with EU contribution** above €20 million. Seven focus on SUMPs, three on Digitalisation (CCAM) and one on climate neutral cities;
- projects L3PILOT, SHOW and SmartEnCity have received the **highest funding**, approximately €36, €30 and €28 million respectively;
- there are 74 **SME-1 projects in total**, however the total EU contribution was relatively low (each project received €50 000);
- there are also **19 projects within the SME-2** funding scheme.

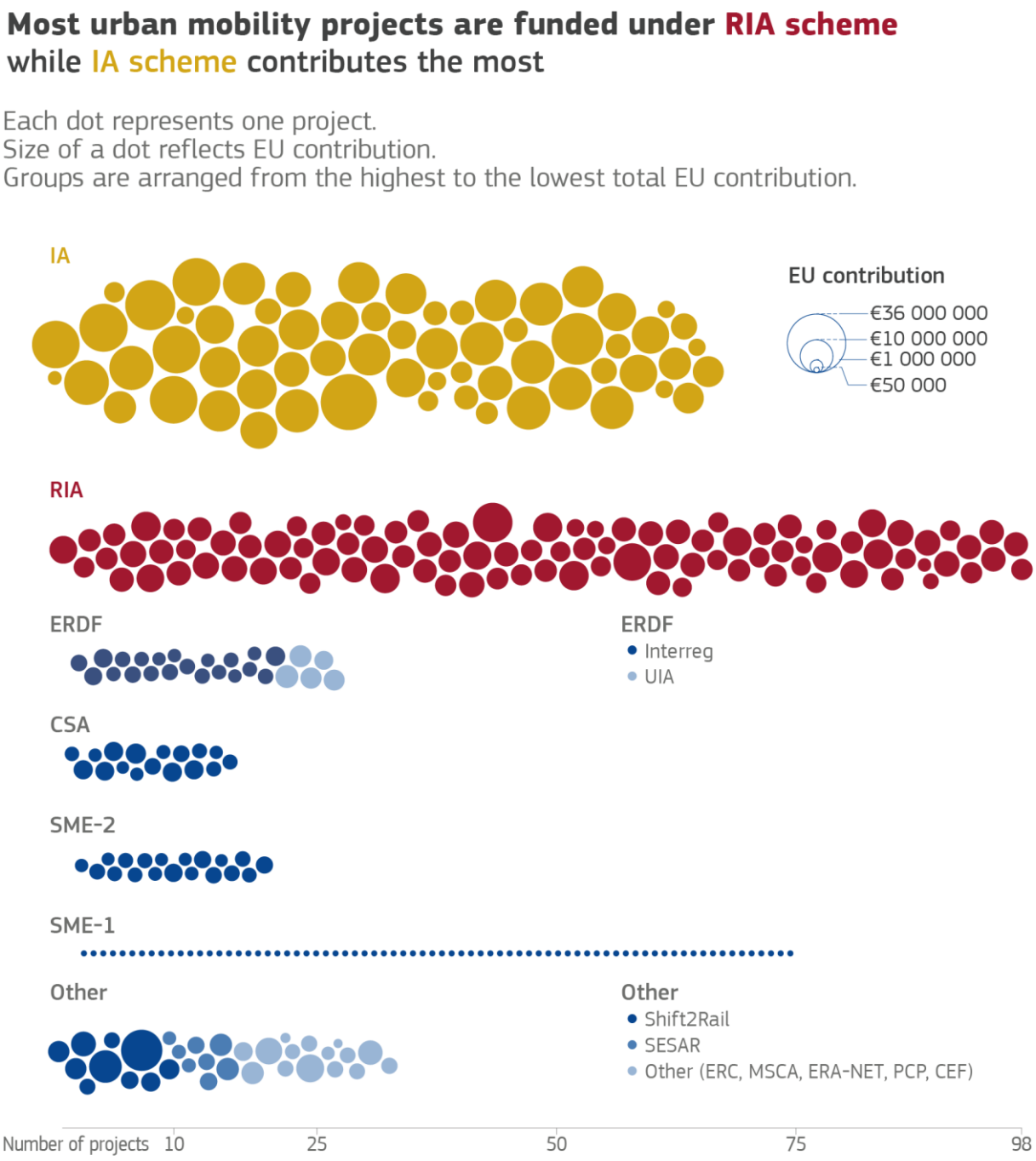
Figure 2. Member State participation in H2020 research and innovation projects [5]



Source: own elaboration based on TRIMIS and CORDIS data

(5) Nine SME-1 and one SME-2 projects are implemented by organizations out of EU and they are not included on the chart.

Figure 3. Urban mobility and logistics research and innovation projects by source of funding



IA – Innovation Actions; RIA – Research and Innovation Actions; ERDF – European Regional Development Fund (ERDF); Urban Innovative Actions (UIA); CSA – Coordination and Support Actions; SME 1 – Small and Medium-sized Enterprises Phase 1 instrument; SME 2 – Small and Medium-sized Enterprises Phase 2 instrument; SESAR – Single European Sky ATM Research; ERC – European Research Council; MSCA – Marie Skłodowska-Curie Action; ERA-NET – European Research Area Network; PCP – Pre-Commercial Procurement; CEF – Connecting Europe Facility

Source: own elaboration based on TRIMIS and CORDIS data

To analyse further, we focus on main trends in urban mobility and logistics R&I activities by assessing the effort directed towards the main identified subthemes (**Figure 4**). The definition of the subthemes follows the aggregation derived from Urban Mobility Framework action plans as presented in the section 0. The identified subthemes cover the following areas:

— **Digitalisation** – covers new mobility services including MaaS, connected and automated mobility, Urban Air Mobility together with ICT, data processes, and digital solutions and services;

— **SUMP** – including urban mobility and logistic planning and management plans, stakeholder involvement, Sustainable Urban Logistic Plans integration;

— **Climate-neutral cities** – including efficient urban transport, recharging and alternative fuels refuelling infrastructure, clean fuels, electromobility, hydrogen;

— **Active mobility** – including walking, cycling and micromobility, modal shift towards active modes, no car solutions, e-bikes and e-cargo bikes, cycling infrastructure, road safety;

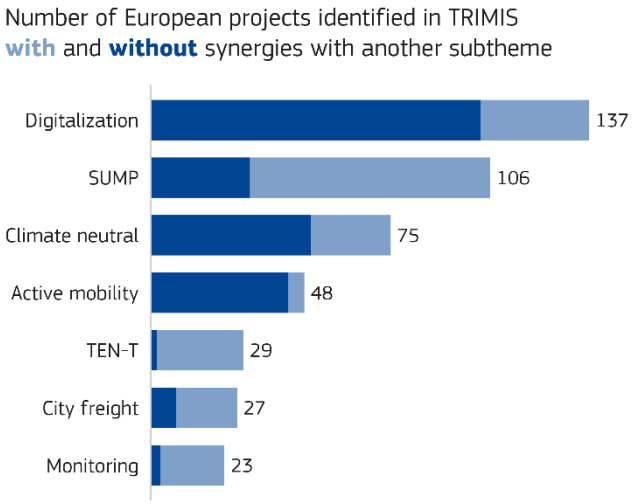
— **TEN-T urban nodes** – including multimodal hubs (passenger and freight), park & ride solutions; (with the special attention to vulnerable road users);

— **City freight logistics and last-mile delivery** – including development and implementation of zero-emission freight urban logistics, last-mile delivery, freight urban logistics infrastructure, new distribution models;

— **Monitoring progress** – sustainable urban mobility indicators including initiatives on harmonised mobility indicators, development and implementation of Sustainable Urban Mobility Indicators benchmarking tools etc.;

Note, that since the scope of a particular project may cover more than one of identified subthemes, a project may be then assigned to one or more subthemes.

Figure 4. Urban mobility and logistics research and innovation projects by subtheme



Source: own elaboration based on TRIMIS data

Main takeaways:

— The highest number of projects (137) focus on **the digitalisation** subtheme. This was to be expected since the subtheme covers many technological developments prescribed by recent policies, including CCAM and UAM.

— The **SUMP** and **Climate-neutral (cities)** subthemes are also in the scope of many projects (106 and 75 projects, respectively). Of particular note, SUMP has higher synergies with other subthemes (mostly digitalisation).

— The remaining four subthemes, **Active mobility**, **TEN-T (**urban nodes), **City freight** (logistics and last-mile delivery) and **Monitoring** (progress) contain less projects reflecting the number of calls and allocated budget in these thematic areas. Almost all TEN-T urban nodes and Monitoring progress projects are also to be found in other subthemes.

4 Key achievements

This section presents key areas of urban mobility R&I and identifies key achievements in each of the areas. It also presents key issues of R&I and an outlook for research directions in the field.

4.1 A reinforced approach to TEN-T urban nodes

The proposed revision of the TEN-T regulation, in alignment with the new Urban Mobility Framework, underlines the importance of multimodal urban nodes for the efficient dispatch of both citizen mobility and freight flows in cities belonging in the TEN-T corridors. Past projects reflect that in their works on intermodal connection between long-distance and last-mile freight logistics. The recently started projects address governance of multimodal zero emission mobility hubs for both passengers and freight.

Project highlights

Project VITALNODES policy recommendations are a precursor to the revision of the TEN-T regulation, and the added focus on the role of urban nodes on efficient and sustainable freight delivery across the TEN-T corridor network. The project brought together existing European, national and regional networks' stakeholders, addressing specifically the multi- and inter-modal connection between long-distance and last-mile freight logistics.

This pioneering work on governance and collaboration has analysed the challenges faced when integrating freight logistics of urban nodes into the TEN-T network corridors. It has provided tools for characterising the urban nodes as Functional Urban Areas examining together spatial and network components, and subsequently providing tools and guidelines to conciliate the requirements of freight and urban activities. Among notable outcomes is a compendium of implemented solutions in the "Nodes Book" ([6]).

The works performed in VITALNODES are reflected in the proposed TEN-T policy revision, and echoed as well in past and ongoing R&I projects addressing:

- Urban planning, such as MORE, which developed data-driven procedures for the co-design of urban main radial roads feeding the European TEN-T network, and explored experimental options such as flexible use of kerb space and dynamic allocation of road space to accommodate different functions.
- Logistics, for example projects on Physical internet such as SENSE, CLUSTERS 2.0 and EPICENTER. These projects explore synchro-modal logistics and cargo flow optimisation, new freight transport technologies such as Hyperloop, autonomous vehicles and modular containers. Urban Logistics and Planning projects, such as SENATOR target dynamic planning and operative optimisation through coordination between urban planners, urban freight logistics actors and citizen engagement.

Recently launched projects SCALE-UP and MOVE21 intend to further build upon and test in pilot cities the governance principles explored in VITALNODES. According to those, passenger and freight transport must be addressed together so that policies, infrastructure (physical and digital), vehicles and energy sources serve both. Among the solutions that will be evaluated are different types of zero emission mobility hubs including integrated energy storage and recharging, as well as integrated transport services. Both projects emphasise the need for cross-stakeholder collaboration (public authorities, researchers, businesses, citizens) in a dynamic open innovation process.

4.2 Sustainable Urban Mobility Plans

Urban mobility keeps increasing in complexity due to the availability of new mobility concepts (such as MaaS, shared transport and micromobility). To deal with this complexity, the need for more sustainable and integrative planning processes was recognised as crucial. The concept of Sustainable Urban Mobility Plans (SUMPs) emerged in EU urban mobility policy documents in 2013 following a broad exchange between EU stakeholders and planning experts. SUMPs allow addressing the strategic planning of all modes of transport within a single, integrated and multimodal approach that is at the same time energy efficient and sustainable. They are based on eight principles that demonstrate the way forward towards a sustainable planning process. The EU supports this initiative through many efforts, including the URBACT programme ([7]) and the CIVITAS initiative.

([6]) https://vitalnodes.eu/urban_nodes/
([7]) https://urbact.eu/

Project highlights

A number of projects develop models and software tools that can help authorities design SUMPs. Other projects focus on collaborative actions that bring together different organisations from different countries in a co-creation process.

SUMPS-UP, PROSPERITY and SUITS are a group of CIVITAS SUMPs-related projects, altogether working towards supporting cities across Europe to develop and implement SUMPs. SUMPs-Up first engages in the systematic information collection, quantitative and qualitative analysis on the status of SUMP across EU MS, and the identification of barriers. Then, it promotes SUMP uptake by fostering collaboration with the organisation of workshops on EU and national levels, with the objective of accelerating uptake of SUMPs where it is low via raising awareness and proposing support mechanisms. These mechanisms include assessment tools, tailored information and implementation support, and finally, the transfer of experience and sharing SUMP culture from partners with advanced and successful implementation of SUMPs. The outcomes included guidelines, and assessment tools, and highlight the good practices derived from living labs experimentation from the seven partner cities. These living labs covered various aspects such as clean air zones, road allocation policy, interactive maps for cycling and walking, traffic forecast, citizen involvement and bottom-up decision making, private entrepreneurship for funding SUMP measures, monitoring SUMP uptake, and freight and MaaS digital monitoring. SUITS takes a specific focus on the capacity of small- and medium-sized cities authorities to develop and implement SUMPS, while PROSPERITY has addressed the gap between local authorities and higher administrative institutions that should provide national support programmes to encourage cities to develop and implement SUMPs, by promoting horizontal exchange, and awareness raising via training for the increase of involvement and activation.

Further CIVITAS projects take the SUMP framework and collaboration, planning and living labs principles and transfer and apply them on specific challenges of particular urban typologies, namely tourist destinations, suburban areas and port cities. DESTINATIONS addresses the specific context of achieving sustainable urban mobility for tourist destinations, which face a fluctuating demand and often struggle during peak season with an increased flow of car traffic putting strain on liveability. The measures evaluated include: introducing and consolidating SUMPs and SULPs, traffic modelling, traveller volume monitoring by digital means in public transport (PT), improving existing infrastructure and adapting for active modes, fleet electrification, promotion of shared modes and MaaS, incentives through shop discounts for public transport users, awareness raising by campaigns and competitions. These measures are evaluated to promote sustainable mobility and thus increase attractiveness of the destinations. In ECCENTRIC, the focus is on suburban mobility, where the challenge is the lower density and challenging public transport planning, and the foremost car centric design. Therefore, measures target among other objectives the safe walking and cycling, uptake of clean vehicles with public charging infrastructure, and efficient and inclusive MaaS and public transport. In PORTIS, the focus is on the specific challenges of port cities, where the challenge resides in the duality of centres of interest (city centre and port), and consequently intersecting mobility and freight flows. Work addressing land use planning, city and port authorities' collaboration, and optimising freight and public transport flows by the use of Intelligent Transport Systems (ITS) is critical for addressing the congestion, pollution and untapped economic growth potential of these cities. The geographic span of pilot programmes covers all of Europe, with port cities located on the North Sea (Aberdeen and Antwerp), the Mediterranean Sea (Trieste), the Black Sea (Constanta), and Baltic Sea (Klaipeda), and even a major international follower port city on the East China Sea (Ningbo).

REMOURBAN developed a Sustainable Urban Regeneration Model (URM) combining energy, mobility, ICT with a citizen-centric approach. This model has been designed to offer holistic integrated approaches to help implement each step of the methodology. The model was implemented and validated between 2015 and 2019 in three Lighthouse cities: Valladolid (Spain), Nottingham (UK) and Tepebaşi/Eskişehir (Turkey). The model and the decision-making process have been tested and fine-tuned in real-life conditions. It consists of four phases (Strategy design, Actions design, Implementation plan, Assessment) across three key priority areas (Sustainable Buildings and Districts, Sustainable Urban Mobility, Integrated Infrastructures and processes) and three key frameworks (City Transformation Management, Evaluation, Financing). The Urban Regeneration Model is available on the REMOURBAN website ([8]).

The CIVITAS HARMONY project is developing multimodal transport planning tools that capture the dynamics of the changing transport sector. The developed model integrates land-use models, people and freight-activity based models, and multimodal network models allowing for vertical planning. The developed software can

([8]) http://www.remourban.eu/technical-insights/best-practices-e-book/best-practices-e-book.kl

support authorities to design SUMPs and virtually test several scenarios before they decide which one to implement. The developed concepts and models are validated on six EU metropolitan areas on six TEN-T corridors. The platform has been applied so far in Rotterdam to simulate Zero Emission Zone scenarios for freight, and in Athens to simulate how traffic flows will change given land-use changes in the area occupied by the old airport.

The CIVITAS SUMP-PLUS creates mobility transition pathways and linked mobility to other components within urban systems (health, retail, education etc.). The project involves six cities in creating City Labs, in which methods and solutions were tested. These solutions are then replicated within "Follower Cities" in a process encompassing mutual learning and evaluation of the achieved targets. A third-tier of beneficiaries, comprised of around 50 other European cities and is crucial to ensuring the legacy of the project outputs. To this aim a "City Consult" Agency has been established, to facilitate city exchanges and transferability, including a comprehensive set of training activities and materials, as well as the continued exploitation following the project's conclusion.

The CIVITAS SPROUT project is focusing on building cities' data-driven capacity to identify, track and deploy innovative urban mobility solutions. The project fostered cooperation within a 3-layer structure, composed by 6 pilot cities, 9 validation cities, and 25 associated cities. In a first step, the project assessed the status of urban mobility in the pilot cities by (i) constructing an inventory of the elements reflecting urban mobility transition, (ii) identifying a set of KPIs to track the current status of urban mobility, (iii) defining the drivers of urban mobility transition, and, (iv) defining the stakeholders affected by the transition. This material has been the basis to create different scenarios for the pilot cities for two different time-horizons (2025 and 2030). The project outcomes contribute towards a revision of the SUMP guidelines to better integrate topics on emerging mobility solutions.

The EN-UAC project aims to create and consolidate a transnational innovation ecosystem for research in sustainable solutions for urban accessibility and connectivity, using resources from 22 research and innovation funding organisations of 16 countries. The project fosters science-policy cooperation by means of integrated approaches, adopting latest technological solutions and using insights both from human travel behaviour and from logistics firms. Solutions researched will be forward-looking focusing in particular on urban accessibility measures in relation with SUMPs and SULPs, aiming at making measures for managing urban accessibility more agile and at the same time effective, robust and impactful, using instruments and tools derived from indicator-based approaches such as SUMI.

In order to reduce congestion as a means of increasing sustainable mobility and liveability in cities, CREATE has analysed congestion from the perspective of car ownership growth and use over time. This has been achieved by a quantitative analysis of congestion and network performance of trends in car use and the related influencing factors, along with several qualitative studies of governance facilitators and constraints.

As outputs, CREATE has developed a methodology and guidelines to support cities transitioning from being car-oriented (stage 1 city) to sustainable (stage 2 city) or liveable cities (stage 3 city, also called city of places). In addition, CREATE explored and analysed the implications of technological and non-technological changes for the cities' transport system and sustainable urban mobility plans.

Project REVEAL tackles the heated question of restricting vehicles access in urban areas, by adding urban vehicle access regulations (UVAR) to the standard range of urban mobility transition approaches of cities across Europe and integrating them into SUMPs. The pilot cities implement a range of measures to favour sustainable mobility for people and goods and prevent vehicles entering into cities. Measures include infrastructure interventions such as redistribution of road space and conversion of parking lanes for sustainable mobility and amenities, pricing measures such as congestion, pollution and parking pricing in order to promote more sustainable modes, and regulatory measures such as traffic regulations and restricted zones (e.g. zero or low emission zones), coupled with complementary measures to ensure access of people and goods and increase public acceptance.

PARK4SUMP focused on parking management as a means of achieving sustainability, by means of SUMP integration, capacity building, implementation of parking measures and monitoring of implementation and impact, for innovative measures such ICT enabled parking management, smart parking apps, e-mobility parking, automated enforcement by scan cars. The project culminated in the development of PARKPAD tool, an auditing process that allows cities to review and evaluate existing parking policies, achieve consensus on improvements and develop action plans.

The MOMENTUM project has employed current ICT technologies, such as Data Science characterisation of activity-travel patterns based on high resolution spatiotemporal data, predictive models for the adoption and use of new mobility concepts such as MaaS, connected and automated vehicles (CAVs) and shared mobility,

and transport simulations, in order to generate plausible future scenarios for the mobility, and thus provide guidelines for the further uptake of SUMP in relation to these disruptive technologies. The project has produced substantial research output with a number of peer reviewed papers and book chapters.

Recent Smart and On-Demand Logistics and Governance R&I projects, such as SENATOR, ULAADS, NOVELOG and LEAD engage with the SUMP policy suggestions, and propose in their methodological approach to support cities in the path towards integrating sustainable and cooperative logistics systems into their sustainable urban mobility plans (SUMPs). They point out the necessity for Sustainable Urban Logistics Plans (SULPs) to support and guide logistics in urban areas, considering that last and first mile logistics put pressure on the liveability of cities. Among the solutions that are examined in ULAADS to promote sustainable logistics are micro-hubs for bike logistics, magnetic levitation pipelines, waterway logistics, barge and cargo bikes combinations, urban railway city cargo, trams and cargo bikes logistics and cargo hitching. Further details on these projects are given in the dedicated section.

While not engaged directly with SUMPs, the GECKO Governance project proposed a comprehensive review of current regulations, current trends in disruptive innovations, and identification or development of KPIs for assessing the sustainability of mobility across all modes not limited to the urban environments, bringing forward policy suggestions.

Certain of the aforementioned projects on SUMPs engage also with mobility management plans, notably SATELLITE, DESTINATIONS, PARKSUMP, INCLUSION, CCCB, and PROSPERITY. Nevertheless, the treatment of the subject is for the moment not extensive, as most studies stop at the theoretical expression of potential of mobility management plans as a tool for changing transport culture for specific mobility groups, such as employees of companies, or tourists in a particular destination. Therefore, this is an area with further potential for investigation and development.

4.3 Monitoring progress – sustainable urban mobility indicators

SUMI (Sustainable Urban Mobility Indicators) is a set of 18 indicators defined by the European Commission that can be used to set objectives and targets.

Project highlights

The development of SUMI started in 2017 based on the World Business Council for Sustainable Development WBCSD suggestions, and was finalised and disseminated in 2019. Taking into account the timeframe, H2020 projects are engaging with SUMI in ways that can broadly be split in two categories:

— Review: notably by projects on the development of Policy and Governance tools as well as Transport Planning, strongly related to SUMP (SPROUT, HARMONY, INCLUSION, SUMP-PLUS). These projects perform a review and analysis of SUMI and other initiatives for defining universal sets of KPIs, and point out:

    - The interest of SUMI as a universal set of indicators that can be used by every city, maintaining a common standard framework of evaluating the move towards sustainability. Attention is given to simplification, measurability, and comparability of KPIs. EU-wide standardised indicators would make it easier for cities to share best practices.
    - The fact that there is a need for cohesion since a common mandatory approach is not defined and each country or local authority applies different rules.

— Engagement:

    - Again, Governance or Transport and Logistics planning projects, such as ULAADS, incorporate them in their workflow, align their proper set of KPIs to this framework in order to further promote their adoption.
    - Projects on diverse technology developments which align part of their evaluation on relevant KPIs. For example, the AVENUE project on Autonomous Vehicles aligns with SUMIs for its Sustainability, Environmental and Economic impact analysis. This is achieved by the use or the Air Polluting Emissions indicator for evaluating the impact of particle emissions from Autonomous Vehicles. Indeed, part of the research indicates that SUMIs can be used in extension to their SUMP scope in order to provide universal benchmarking for R&I.

To further support cities in data collection and guidance on indicator calculations, the ELTIS/SUMI2 ongoing project both provides technical assistance for the application of SUMIs, and sets up the European Urban Mobility

Observatory, Europe's main observatory on urban mobility which provides good practices, tools, and communication channels needed to help turn cities into models of sustainable urban mobility.

4.4 Healthier and safer mobility: a renewed focus on walking, cycling and micromobility

Active mobility modes can either be part of multimodal trips or can be exclusively used as door-to-door solution. Walking and cycling are low-cost and zero-emission forms of mobility thus they have a great potential to improve human health and reduce emissions. The new UMF states that SUMPs should aim to increase the use of active mobility. Through promotion of active mobility, supplemented by transport and urban planning decisions and adequate infrastructure developments, urban areas may achieve more sustainable modal split, reduced congestion and decreased air and noise pollution, reducing health risks for the whole urban population, and having direct health benefits for active mobility users.

4.4.1 Promoting active mobility for all

Several cities developed their own path towards increased use of active mobility. Moreover, they all operate in different climate, legal, spatial, social and economic conditions. In consequence, the knowledge 'what works', why and under which conditions is mostly fragmented, hard to implement and it is difficult to evaluate to what extent particular solutions are successful. Several projects have tackled these obstacles, by applying a holistic approach to cycling and walking uptake, catalogue best practices and developing methods for walking and cycling modelling.

Project highlights

The CIVITAS HANDSHAKE project has applied a holistic approach for embedding cycling into multidisciplinary planning culture. The consortium has identified more than 60 measures across 23 different types of solutions, which are designed to increase attractiveness of everyday cycling. Solutions are grouped into four categories covering planning, regulations and standards, modelling and assessment, infrastructure and services as well as awareness and education. For each of the solutions a dedicated factsheet is created providing detailed information on how the solution is implemented in leading and following cities. The planning tool COMPASS, developed in the context of the project, can calculate which socio-economic groups will be most affected by certain traffic-policies such as parking fees, road pricing or investments in bicycle infrastructure. Furthermore, it allows the estimation of emissions, health effects and effects on travel time, thus facilitating cities to plan and prioritise bicycle infrastructural development.

Modelling of active modes is crucial for proper transport planning in urban areas as well as for monitoring of promotional activities undertaken by authorities in order to increase walking and cycling.

The FLOW project tackled the challenge of monitoring and evaluation of the contribution of active modes to congestion reduction. The project developed dedicated tools which enable to evaluate the impact of active modes on congestion (including socio-economic impact, an assessment of soft measures, congestion evaluation based on KPIs and a cost benefit analysis) as well as traffic modelling (as an extension for widely used software in the area), and advocates for a holistic planning approach, including the health effects.

The aim of TRACE was to explore the potential of walking and cycling tracking services to promote walking and cycling mobility. The project has focused on walking and cycling promotion measures (such as: Traffic Snake Game, Biklio and Positive Drive) and assessed the potential of ICT-based tracking services to overcome barriers in implementing these measures. Through specific research, the related ICT challenges like scheme dynamics, privacy, trust, low-cost, interoperability and flexibility were tackled for each type of measure. The main innovation outputs of the TRACE project are: the improved/enhanced Positive Drive app, the "automated" Traffic Snake Game, the new Biklio tool and the TRACE tracking for planning tool (TAToo).

The ALLEGRO project aimed to establish a comprehensive theory of active mode traffic behaviour. Using a mix of 'traditional' (extensive surveys, controlled cycling and crowd experiments) and 'modern' (virtual reality, GPS tools, data collection using Wi-Fi and 3D sensors) data collection methods, the project developed detailed models which can be used to identify and predict active mode flows in urban areas.

Additionally, promotion of active modes is in the scope of several Interreg projects. All the identified and evaluated projects focus on walking and cycling, however they differ in terms of specific angles they look on active mobility.

The EU CYCLE project collects good practices of regional action planning to promote cycling as a sustainable, healthy and efficient transport mode. The collected good practices include cycling promotion (e.g. Bike to Work Day, gamification tools), Bike & Ride rail services in cross-border settings, bicycle parking facilities as well as examples of efficient network cycling infrastructures (e.g. long-distance cycle routes or cycling highways).

The CYCLEWALK project gather best practices and developed action model which defines how to implement those practices and how to track their implementation. The included best practices focus on walking and cycling infrastructure and they cover guidelines for pedestrian and cycling infrastructure, walking and cycling network developments along with transformation of existing roads towards active mobility use, a platform and mobile applications for reporting infrastructure problems in a city along with example of Bike & Ride rail services in cross-border settings.

The SCHOOL CHANCE project concentrates on promotion of active modes for school trips. It developed an interregional learning programme along with action plan implementation. It also established a School Mobility Manager Network to foster sharing of experiences and mutual learning, developed methodology for safe routes to schools and identifies good practices covering various types of cycling campaigns (including winter one or European Cycling Challenge), cycle exams, school zones or provision of free public transport for pupils.

The DESTI-SMART project aims to improve tourism and transport regional policies by integrating strategies for sustainable mobility, accessibility and responsible travel with efficient & sustainable tourism development and transition to a low-carbon economy. It collects sustainable and smart mobility solutions for tourist destinations and identifies good practices which aim to foster interactions between tourism and transport sectors (e.g. electric bus shuttle and on demand services for tourists, combined tickets or Bike & Bus services).

Finally, it is worth mentioning projects pertaining to urban logistics that promote last mile delivery by active modes, such as CITY CHANGER CARGO BIKE, detailed in the dedicated section 4.6.2 below.

4.4.2 Technology development for cycling and micromobility

New mobility services can reinforce public transport and substitute car use as part of a multimodal, integrated approach to sustainable urban mobility. Recently, multiple new operators have started to offer new micromobility services, while privately owned micromobility vehicles of various types are also more and more common. However, the emergence of new forms of micromobility on city streets increases the number of vulnerable road users. This issue should also be addressed from regulatory point of view, and potentially require further technical innovations. Moreover, several other obstacles still need to be overcome, including those related to cost, comfort or range (in case of vehicles with electric support, like e-bikes or e-scooters). Finally, specific needs of the most vulnerable groups should also be satisfied, e.g., people with reduced mobility, older adults and others.

Recent projects in the area concentrated on developing and testing prototypes of various micromobility vehicles. Their primary use would be in dense, urban areas. The projects also worked on supportive apps for micromobility management.

Project highlights

RESOLVE, ESPIRIT and LEONARDO projects focus on prototypes of four-wheel, lightweight vehicles. RESOLVE focused on advanced energy management strategies reaching high efficiency level of designed vehicles. The project proposed also an innovative business model combining vehicle sharing and battery swapping solutions. ESPIRIT developed a prototype of a lightweight, four-wheel electric vehicles which can be then nested in a road train. Nested vehicles can be used on main links during a trip, and for the last mile travel they can operate as an individual vehicle. The vehicles were tested in three different urban areas in three countries. The innovation could increase efficiency of car sharing services, however, so far it has not come on the market. Recently started project LEONARDO aims to develop a prototype of modular e-scooter for which electric motor power and other aspects can be easily adapted to fit different regulations in particular country. Finally, STEVE collected information regarding prototypes development, user experiences, success stories and business models and it developed a white paper on the future vision of electric light vehicles as means of transport.

Projects FREEWHEEL and TORQWAY HYBRID are examples of projects that focus on specific needs of people with reduced mobility. FREEWHEEL developed a system of sensors required to enable control of the motor and autonomous navigation which then were added to the prototype of motorised wheelchair. The projects outputs reach a Technology Readiness Level (TRL) of 6 which consists of autonomous individual unit and ICT mobility platform accessible through smartphone. The TORQWAY HYBRID project developed a prototype of microvehicle which requires physical exercise to move. The vehicle is powered by arm movement and the type of exercise is

suitable e.g., for older adults and it supports flexibility of joints and improve coordination. In return it offers electric motor assistance which permits to travel with double walking speed (up to 11km/h) and flexible range of travel (depending on level of motor support).

Several SME-1 projects worked on innovations for cyclists, including Bicycle Anti-Lock Brake System (ABS) for Cycling (project BIKEABS), increasing cyclists' visibility (project BLINKERS), electronic shifts for bikes (EVOTRANS) or recuperation systems for e-bikes (projects LONGRIDER and VELLO CMC). The latter developed the VELLO BIKE+ innovative self-charging lightweight folding bike which has made its way to the market, and it is now offered to clients in EU and EFTA countries.

Another SME-1 success story is related to SMART BIKING project, continued under the Small and Medium Enterprise Phase 2 instrument (SME-2) scheme. The project developed bike parking infrastructure which would be safe, easy to use and install, low-cost and energy autonomous. The current version of the developed innovation has been extended to be used not only for bikes but also for scooters. The vadeCity company behind the project is now operating in Barcelona (with currently 46 stations in the city and its surroundings).

4.4.3 Sustainable urban neighbourhoods

Neighbourhoods are of particular importance for urban planning as it is the geographical level where everyday life unfolds. Ensuring and improving quality of life in neighbourhoods is closely tied to the promotion of active mobility, measures on traffic management such as traffic calming, and infrastructural changes to promote public and street space quality and reorganisation to accommodate walking and cycling. Furthermore, the neighbourhood geographical scale allows for citizens and local businesses to be empowered and participate directly in the decision-making process as they have a clear view of local challenges and can thus propose ideas and solutions.

Project highlights

The CIVITAS project SUNRISE has developed co-creation mobility labs in selected action neighbourhoods in six cities. The labs have systematically involved citizens, businesses, NGOs, local authorities, academics, and strived to also involve under-empowered sections of the population like migrants, women, older and young people. The methodology included the deployment of "citizen science" as a means of citizen engagement, the use of the internet as tool for interactive, more inclusive and more transparent participation; and also, as a tool to mobilise "crowd wisdom", collective intelligence and creativity. On a strategic level, SUNRISE has advocated for a Sustainable Neighbourhood Mobility Planning concept (SNMP) to complement SUMPs.

MUV, which stands for mobility urban values, is based on behavioural science and gamification in order to change citizens' habits through a game that mixes digital and physical experiences. The spin-off application which is available on mobile stores incites communities, local businesses and policymakers a shift towards more sustainable and healthy mobility choices. As further outputs, the anonymised mobility data collected by the application can be further analysed by policy makers and stakeholders for future planning, and the application can be used for the mobility plans of specific populations, such as schools and universities or businesses.

The METAMORPHOSIS project focused on the transformation of car-oriented neighbourhood space into children-friendly neighbourhoods, with the aim of achieving behavioural change and increase in the quality of life. Towards this goal, it engaged in user involvement and needs identification, and the development of innovative concepts, with children as the main stakeholder group in all steps. Experimentation and capacity building were examined for a set of measures, such as temporary street closures and interventions in public space, as well as educational innovation tools, empowerment activities for children as important stakeholders. Finally, the outputs suggest improvement of planning procedures and integration into SUMP planning.

The LOOPER project was equally a project oriented on co-creation, as a means to bridge the gap between citizen needs and local government planners, leading to a circular interactive decision-making loop. It advocates for a community-based visioning and design, claiming that it leads to better neighbourhoods. The co-creation process includes active involvement and empowerment of citizens to collect data, design solutions and monitor the outcomes. The co-creation model and toolkit were employed in three Looper Living Labs in Brussels, Manchester and Verona targeting to obtain practical solutions for air quality, noise, safety, security, greenspace and other challenges in the public realm, using mobile apps for environmental monitoring, dashboards for spatial data visualisation and finally offline and online co-design platforms for conceiving solutions.

4.5 Urban freight and logistics

Research and Innovation activity in the domain of urban freight and Logistics can be broadly split in two categories:

1. Governance, planning and collaboration projects that aim to analyse and comprehend the urban freight needs and position them in the urban mobility context and propose solutions, in the form of guidelines, policy suggestions and decision-making tools, creation of stakeholder networks, and ICT based tools for logistics planning, and finally deployment of solutions in pilot cities, evaluation and upscaling. Particular focus in recent projects is given to the on-Demand Economy and e-Commerce which are in rapid development, which can be attributed to a significant extent to the mobility restrictions applied for COVID-19 propagation mitigation. Even after the lift of restrictions, the On-Demand economy continues to grow, putting strain on the urban mobility networks and urban liveability by extension.
2. Technology R&I projects, which aim at developing part of the solutions necessary for the deployment of the goals set by policy and stakeholders, starting from the infrastructure, multimodal hubs, charging infrastructure, and network design and development, the ICT solutions necessary for managing and optimising the concurrent flows of citizens and goods through multi-modal means, as well as solutions for the sustainable transport for urban and last mile delivery. Several SME projects fall under this category, concentrating on the ICT solutions for flow management and logistics actors' collaboration, and last mile delivery vehicles.

Project highlights

The next two sub-sections report the project highlights for the two categories. Beyond that, the recent BOOSTLOG project has already mapped 295 EU-funded R&I projects since the 5th EU Framework Programme for Research in different freight transport and logistics domains. The project analyses how project outcomes were taken up by the market, identifies R&I gaps and provides recommendations in the form of 11 future R&I priority actions in contribution to the EU policy objectives.

4.5.1 Governance, Planning and Collaboration

A first line of research of governance projects focuses on (i) understanding the urban freight needs and placing freight flows within the whole urban context, (ii) urban logistics on demand, (iii) business models and partner collaboration, (iv) scenario making, and, (v) participatory governance.

The PROSFET project provides a review of urban freight transport in Europe, by highlighting best-practices and sharing them across a network of public bodies; it focuses on the promotion of the utilisation of stakeholders' engagement methods in urban freight transport policy formulation and on strategic decision making in Europe, as well as on the use of decision support tools for urban freight transport by public authorities in Europe.

The NOVELOG project, focused on the targeted understanding of urban freight and service trips, fostered by data collection on city logistics, field testing and implementation of representative city logistics measures, the development and application of a modular, integrated, evaluation framework for the assessment of these measures.

The SCALE-UP project aims to improve multi-level governance models and multi-stakeholder cooperation, including innovative governance models (role of the city within urban area and TEN-T network), Public Private Partnerships (PPPs) and Financial and institutional cooperation models for the entire spectrum of urban mobility, including urban freight and logistics.

Starting with a co-creation process to model future on-demand scenarios for urban logistics and a definition of relevant delivery solutions, the ULAADS project proposes new schemes for horizontal collaboration (driven by the sharing economy). These schemes include crowd logistics, sharing of assets between stakeholders, leading to re-think the value of 'ownership' and 'use' in the urban logistics sector, testing shared, connected and zero-emission solutions for cost-effective delivery. Considering the uncertainties generated in urban logistics for city planners and that SULPs need adaptive capacity to deal with change, a workshop co-organised by project partners focused on resilience planning ([9]). Increase in knowledge, skills and capabilities, together with a monitoring process capable of identifying "silent" problems, and a set of adaptive actions prepared in advance

([9]) https://ulaads.eu/resilient-planning-for-sustainable-urban-logistics-workshop-recap/

and deployed responsively, and finally, collaboration among the different stakeholders involved, is key to resilient planning.

The SENATOR project is based on a multi-level system model for urban space management promoting sustainability and shared-connected freight and delivery services in cities. Its main ambition is the smart network operator "control tower" approach, allowing dynamic planning and ensuring operative optimisation through a fluent relationship between urban planners, urban freight logistics players and citizen engagement.

A second line of governance projects focuses on multimodal transport systems for passengers and freight.

The ULAADS project aims to develop sustainable and liveable cities through re-localisation of logistics activities in multi-modal hubs, using a combination of innovative technology solutions (vehicles, equipment and infrastructure), and smart points in the transport network that seamlessly integrates different modes of transport through multimodal supportive infrastructure; including car sharing parking slots, bike-sharing docks, public or collective transport stations, EV-chargers and public cargo bike-sharing platforms.

As a particular showcase of a holistic approach, SCALE-UP is engaging in all aspects of urban mobility and logistics, beginning from the planning and design of multimodal transport systems for passengers and freight including multimodal hubs with emphasis on Park&Ride, shared e-vehicle fleets and active mobility options, and the optimisation of networks for optimal integration of hubs.

The CIVITAS CITYLAB project focused on zero-emission city logistics, being a pioneer in implementing, testing and evaluating promising logistics concepts in Living Labs. The project focused on four areas requiring intervention: (i) highly fragmented last-mile deliveries in city centres, (ii) inefficient deliveries to regular recipients of large deliveries and public administrations, (iii) urban waste, return trips and recycling, and, (iv) logistics sprawl, i.e. the tendency of warehouses to move away from urban centres toward more suburban areas.

On specialised items of particular interest for urban logistics, CIVITAS SUCCESS focused on logistics for construction sites while U-TURN addresses food logistics.

As cities continue to grow and densify requiring constructions and infrastructure, the SUCCESS project up to its conclusion in 2009 has investigated supply chain management and construction consolidation centres (CCCs). Among the solutions investigated are optimisation tools for the construction supply chain, such as radio Frequency Identification (RFID) and Geographic Information System (GIS) technologies, e-collaboration tools, and process mapping. The numerical simulation tools developed allow to establish scenarios with and without CCCs to assess potential solutions, a selection of which has been evaluated experimentally directly on pilot sites.

U-TURN investigates the potential of shared and collaborative food distribution, by means of simulation tools calibrated on data collected from pilot cities, and both numerical and living labs experimentation. The project results suggest improvements in distance travelled, vehicle emissions, and nuisance to society from logistics activities. Among the success stories reported in implementing e-cargo bike deliveries for groceries which outpaced standard delivery, and national policy impact concerning the implementation of urban consolidation centres (UCCs).

The MOVE21 project recognises that passenger and freight transport must be addressed together so that policies, infrastructure (physical and digital), vehicles and energy sources serve both. Different types of mobility hubs and associated innovations are tested on urban nodes belonging to the Scandinavian-Mediterranean (Scan-Med) TEN-T corridor, and means to overcome barriers for clean and smart mobility are deployed. The project outlines the use of modern transport modelling approaches and simulations (e.g. digital twins and agent-based modelling).

Finally, a third line of research focuses on pilot deployment, scaling and evaluation. This is common in every aforementioned governance project, since they all have the ambition to implement its policy suggestions. The approach is similar between projects, with the Living Labs pilot cities testing the solutions and replicator cities evaluating the repeatability of the experiments, and finally cascade cities for the propagation and take-up of the best practices.

4.5.2 Urban logistics technology

A first line of research focuses on data driven strategies and tools, simulation and digital twins, ITS, Software as a service (SaaS), modelling and optimising logistics flows, data framework (new approach to data capturing, data analytics, business intelligence), and data security.

The SCALE-UP project focuses on developing data driven strategies and tools, including a data framework (new approach to data capturing, data analytics, business intelligence), and the translations of regulatory frameworks into open data services for MaaS providers.

The ongoing LEAD project creates simulation-based digital twins of urban logistics networks, to evaluate different scenarios and logistics strategies, such as agile urban freight storage and last mile distribution, including crowdsourced shipping, capacity sharing, multi-echelon and Physical Internet inspired approaches, in six cities representatives of EU diversity in terms of urban, social and governance conditions, to enable informed decision making with on-demand logistics operations in a public-private urban setting. The project culminates in roadmaps towards zero emission urban logistics, sharing of the LEAD digital twins tools and guidelines for their use in SUMPs and SULPs.

The CIVITAS City Changer Cargo Bike (CCCB) project focused on (i) identifying the optimal packing and routing to improve last-mile delivery using cargo bicycles, on modelling demand for deliveries by cargo bicycles, on (ii) the substantiation of loading hub location for electric cargo bikes servicing city areas with restricted traffic, and, (iii) on an approach to simulations of goods deliveries with the use of cargo bicycles.

The COG-LO project added cognition and collaboration features to logistics processes, by using data about missed deliveries, daily delivery fluctuations in a systematic way for providing logistic plans that anticipate operational noise due to external factors such as road traffic conditions, unexpected delivery problems etc. In addition, it aimed at enhancing security and privacy through a holistic access and usage control framework. The project evaluated its results also through urban logistics pilot operations.

A number of SMEs engage in different aspects and solutions of urban logistics and last mile delivery, trying to improve its efficiency (COLLOGISTICS), decoupling source and logistic service provider (LOOP) by the use of a single platform with PickUp and Drop off Delivery points and predetermined circuits, cargo capacity optimisation based on AI predictions for the demand (PREDICTS), leading in pilot testing up to 10% increase in capacity utilisation and 7-9% cost savings, and a delivery system (iMMI Transport) based on an online platform which connects 'job requesters', those with a need for goods transportation, such as online shops, laboratories & private individuals, with 'transporters', professional bike courier partners or casual transporters from the citizen population. Most of these solutions for logistics optimisation, such as AIRMEE, are proposed as SaaS platforms, able to be adapted in different situations.

A second line of research focuses on clean and safe logistics vehicle and technologies.

The URBANIZED project designs modular all-electric Light Commercial Vehicles (LCVs) to cover for requirements for sustainable last-mile delivery in the design of modular all-electric LCVs with the right dimensions for the mission, and SYS2WHEEL develops electrified components.

Various SMEs investigate innovative designs for small sustainable cargo vehicles, such as the three-wheeled BICAR with a small surface and weight footprint and innovations such as solar roof, swappable batteries and sustainable construction, or CARR-E that can transport a payload of 160Kg autonomously for 90Km, while "HAVE A BLAST" proposes "K-Ryole", an electrically assisted trailer which can carry a load up to 250 kg, which can be attached to a bicycle's seat tube and convert it into a cargo vehicle.

Container technology, including solutions developed in the projects SMARTCOOLBOX and LOGIST-IOT the use of light and degradable materials, offering isothermal conditions and smart sensors for tracking the conditions of the transport ensuring its monitoring and safety. ULAADS proposes also a containerised urban last mile delivery solution for optimising the vehicle occupancy rates.

4.6 Cooperative, Connected and Autonomous Mobility in urban environment

The emergence of Cooperative, Connected and Autonomous Mobility (CCAM) technologies will transform European mobility, especially in an urban context. For example, the use of autonomous shuttles has the potential to make transport operations more efficient, ultimately leading to a reduction of the number of private vehicles on the streets. In the urban context, the deployment of autonomous vehicles requires the infrastructure (physical and digital) to enable vehicle connectivity.

There are however some hurdles for the implementation of CCAM in urban context. The urban environment brings a lot of nuanced complexities to traffic, such as dangerous intersections, interaction with pedestrians, cyclists and other vulnerable road users, construction sites and dense traffic. Additionally, the expected uptake of autonomous motorised mobility will require autonomous vehicles to share the road with standard vehicles, which also poses challenges. Beyond that, to ensure that new technologies bring about the expected benefits,

public authorities must define and coordinate all actors in the public interest and establish efficient and equitable governance for complex, multimodal transport systems ([10]).

Project highlights

The successful deployment of autonomous vehicles relies on several technologies, which are integrated and functioning together. Therefore, testing these technologies under real environments is crucial to be able to evaluate their readiness for deployment, along with points for improvement. The L3PILOT project carried out several tests on public roads, with the objective of testing the viability of automated driving functions in vehicles. Within their urban pilot, the project consortium concludes that systems for automated functions are still at a lower readiness level for urban use (when compared to highway use), and that due to the high complexity and variability of urban environments, it is more challenging to evaluate such systems and to define robust use cases. The project also concludes that there is the need to acquire large amounts of data to be able to cover all aspects of automated urban driving.

While the potential benefits that CCAM can bring to cities are quite high, technical and operational requirements are among some of the obstacles before autonomous vehicles can be fully deployed in cities. The COEXIST project evaluated the impact of CAVs on urban traffic efficiency, road space requirements and safety, while guiding local policy discussions. Four local city authorities were involved in the project (Gothenburg, Sweden, Helmond, the Netherlands, Stuttgart, Germany and Milton Keynes, United Kingdom). The project also developed a framework to support local authorities to plan CAV deployment, reducing uncertainty and building up capacity. A practitioners' briefing developed within the framework of the project provides guidance and best practice examples for the introduction of CCAM in SUMP processes ([11]).

The coexistence of autonomous vehicles and conventional ones is an important topic, especially when it comes to safety and efficiency, as these can go down in case no proper measures are taken when both types of vehicles share the roads. The INFRAMIX project investigated such cases, creating distinct scenarios to test the mixed autonomous and conventional vehicle situations. The project applied two real world tests in Austria and Spain, introducing traffic control strategies and implementing the required physical and digital infrastructures for the proper management of mixed traffic flows.

Automated vehicles rely on positioning systems for safe and efficient operations, with high accuracy and robustness requirements. With this goal in mind, partners of the PROPART consortium developed a solution which combines Galileo signals with vehicle sensors and infrastructure, which can provide a highly accurate position estimation for vehicles, even when GNSS coverage is poor, such as in tunnels or urban canyons. The project carried out a successful demonstration of the developed system at the AstaZero Proving Ground in Sandhult, Sweden. The developed final system is now available as an off-the shelf prototype and available to further collaboration and development.

Similarly, the ALBORA project investigated how to provide robust, reliable and precise vehicle position data to be used for autonomous driving. The project consortium designed and patented an artificial intelligence engine, ALCORE, which combines different sensor data and uses a powerful algorithm to provide high-precision geolocation which can be embedded in the current technology available for autonomous vehicles.

4.7 Safe urban mobility

Safety in the context of urban mobility is persistently an important topic, which can be examined from the prism of the global target of Vision Zero for road transport. With the increase of number of pedestrians and cyclists, there also comes the need for safety, especially in cases where they are sharing the streets with motorised vehicles. Moreover, with the deployment of autonomous vehicles comes a new challenge in ensuring safety of vulnerable road users, with the need for testing the new technologies. There is also the need for communication infrastructure that is intended to improve road safety through vehicle connectivity.

Research challenges in the area include the need for in-depth investigation of vulnerable road users and their needs, as well as urban driver behaviour, especially at higher risk areas, such as critical junctions and roads with high number of incidents. Another area is the research in infrastructure and how its elements can contribute to a safer mobility. For example, studies are needed in how street signs or even digital signalling, as well as

([10]) European Commission, Joint Research Centre, The future of road transport : implications of automated, connected, low-carbon and shared mobility, Publications Office, 2019, https://data.europa.eu/doi/10.2760/668964

([11]) https://www.eltis.org/sites/default/files/road_vehicle_automation_in_sustainable_urban_mobility_planning_0.pdf

vehicle to infrastructure (V2I) communication. Within CCAM, there is the need to ensure hardware and software robustness, with failsafe mechanisms make sure that safety is preserved even in exceptional situations. A safe-system approach is taking shape, as a means of integrating available safety solutions on infrastructure and planning, vehicle safety design, behavioural and social aspects. This is expected to address the multi-disciplinary, multi-sector and multi-stakeholder aspects of road safety and approach thus Vision Zero.

Project highlights

With safety being a great concern for road transport, new solutions are sought when it comes to encouraging safe behaviour from drivers. To influence drivers' behaviours and steer them away from risky habits, the MEBESAFE project developed an alert interface in car displays, to warn drivers when they would be approaching a dangerous crossing, or in accident-prone locations. Additional measures developed by the project include ways of inducing drivers and cyclists to slow down, such as using road stripes that gradually get closer when approaching a dangerous location, giving the perception that they are moving faster, leading to a slow down. The proposed safety measures were tested with success in two major cities (Gothenburg in Sweden and Eindhoven in the Netherlands).

When it comes to safety, there are numerous scenarios that should be accounted for, when designing hardware and software for autonomous vehicles. However, due to the high number and conditions related to safety, it is not feasible or possible to test every single scenario in real life situations, especially when investigating reliability of systems in autonomous vehicles. For this purpose, the AUTODRIVE project aimed to create self-diagnostic systems and fail-safe components in software and hardware. Moreover, a co-simulation platform was partly supported by the project, which can be used to evaluate design methodologies and assess functional safety requirements of autonomous vehicles, based on a scenario database.

Within the infrastructure context, vehicle communication and connectivity can play an important role in improving road safety. The SAFE STRIP project set out to create novel road markers which contain micro or nano sensors. In this way, functionality for connected intelligent transport systems (C-ITS) applications can be achieved, while also ensuring that vehicles that are not equipped with connectivity functions can still safely drive. Such sensors can be placed at any necessary location, such as railway crossings or road work zones, and be able to provide information to connected vehicles about any hazards or dangers ahead, without disrupting the actual road signs. The proposed solution was first tested in test beds in Spain and France, and subsequently used in demonstrators in Greece and Italy.

Cyclist are one of the most vulnerable groups of road users. Cycling safety is then one of the main potential obstacle for the successful cycling uptake. Having cyclists' safety in mind, the XCYCLE project developed several sets of safety systems. For example, sensor-based detection systems are designed to facilitate detection of cyclists (e.g. at intersections), while another system warn a driver that cyclist is in a vehicle's blind spot. All the systems together are design to work together in order to increase safety of cyclists which is particularly important in dense urban areas.

4.8 Mobility as a Service

Mobility as a Service (MaaS) schemes have the potential to disrupt the way citizens and freight move in the future. MaaS will offer users mobility options as a viable alternative to own mobility and car ownership, combining transport infrastructures, travel information, payment services and more. Challenging car ownership can be achieved by offering one-stop shop MaaS platforms. This is a key to offer citizens an alternative that includes more sustainable public transport options.

The MaaS concept is acknowledged in the EU Sustainable and Smart Mobility Strategy and in the new UMF, as a mean to alleviate the increasing pressure on passenger transport systems and for making interurban and urban mobility more sustainable. Optimal cooperation between all mobility service providers are main challenges for rolling out MaaS ([12]). Due to the implied challenges of public/private mobility integration, information handling and sharing, service interoperability and scalability requirements, specific actions to accelerate an appropriate and sustainable take off of MaaS solutions are needed.

([12]) European Commission, Joint Research Centre, Muench, S., Stoermer, E., Jensen, K., et al., Towards a green & digital future : key requirements for successful twin transitions in the European Union, Publications Office of the European Union, 2022, https://data.europa.eu/doi/10.2760/977331

Project highlights

The MAAS4EU project considered the MaaS operator as an intermediate enabler between transport operators and users. Under this scheme, the MaaS operator can propose the ideal combination of transport modes to the users by knowing the network conditions in real time (supply side) and the preferences of users (demand side). The project developed business models and travel behaviour models and explored aspects related to personalised dynamic and multi-service journey planning in three pilots in Manchester, Budapest and Luxembourg.

IMOVE developed a framework of software enablers, Information and Communication Technologies (ICT) components integrating and enhancing the technological level of a MaaS. It put on the spotlight both the supply and demand sides. The former focused on how the mobility offer spreads across transport modes (public transport, shared mobility, railways) operated by various public and private operators and agencies. The latter covered how the users are willing to travel with ease in the most effective way according to the available options and their preferences. The project solutions were validated in living labs.

One of the emerging issues is that existing transport models are designed with the principle that transport consists of either fully scheduled and controlled collective fleets or individual privately owned vehicles. MaaS breaks this conventional division and thus there is a need to change the behavioural models. CRITICALMAAS is developing and testing transport network theories and models to study emerging patterns, transition phases and critical concepts.

The MAASIVE project focused on IT solutions in the areas of travel shopping, trip tracking, booking and ticketing, and the development of a travel companion application for smartphones.

The MYCORRIDOR project developed stand-alone digital service and software products, including a MaaS platform with front-end mobile application. The projects target was urban, interurban and cross-border travellers over six pilot sites in Europe, and included different target groups (commuters, elderly people, mobility restricted people and tourists). The developed app provide to the traveller a single payment mechanism for all trips, by combining the back-offices of different public and private transport operators into a single platform.

SHIFT2MAAS conducted pilot demonstrations in different cities for assessing the success of the "technology enablers" in MaaS. It evaluated the results, including the operator perspective, establishing a common methodology and set of relevant key performance indicators (KPIs). The real-world data gathered from the demonstrations helped to improve solutions and understanding of possible bottlenecks in their implementation from policy, regulations, technology uptake and legacy systems readiness perspective. The IP4MAAS project is conducting demonstrations testing technologies in different contexts in six cities across Europe (Barcelona, Padua, Athens, Osijek, Liberec and Warsaw). The first pilot in Athens was launched on 11 July 2022 focusing on enhancing multimodality by proving journey planning and integrated ticketing through a single travel companion application.

The Interreg PRIMAAS project is developing public–policy instruments to help public authorities in supporting MaaS. The new platforms should contribute to low carbon transport policy goals, social inclusion and increased levels of accessibility. The project aims at increasing collaboration between European regions to build trust among key stakeholders (for example transport authorities, traffic operators, providers of mobility service apps and consumers protection organisations).

HIREACH is a project focusing on inclusiveness for vulnerable mobility user groups and fighting against "transport poverty", exploring viable business models for small scale, modular and easily replicable mobility services (e.g. community transport services, ridesharing, minibus pooling, etc.) that can be provided at affordable prices and/or with minimum subsidies. This is achieved with the engagement of 25 startups which tested flexible transport solutions for different social groups poorly served by traditional transport options like scheduled buses and trains and taxi services. Attesting to the project's success, 9 of them announced they were ready to launch on the market by its end.

4.9 Shared mobility services

The car continues to be the most common mode of transport in the EU for the most frequent trips. However, cities are adopting nowadays shared-car-based mobility schemes to reduce car use, vehicle emissions, parking spaces and to promote greener transport modes. Shared mobility projects (including car-pooling) aim to decrease travel times and costs, to increase comfort and convenience and to contribute to a better environmental performance of urban transport networks, fostering at the same time social inclusion, service orientation for citizens, accessibility of urban areas and transport efficiency.

Project highlights

The STARS project aimed to close the gap between the potential benefits of shared vehicle services, and their real impacts in terms of congestion mitigation, environmental footprints and social inclusion. The project assessed the role of car sharing in improving mobility in European urban areas, including new business opportunities to the automotive sector as well as the impact of car sharing on other travel modes (public transport, active means, private cars). They studied two scenarios: business as usual and rupture mobility. Two simulations in Italy, in Turin and Milan, with fully electric car-sharing fleets found a 3.6% reduction of daily costs for society deriving from the emissions of CO_2 and air pollutants.

SOCIALCAR identified requirements, and, defined use cases, data models and algorithms, to develop a software platform for carpooling in urban and peri-urban areas, which was afterwards deployed in the cloud. The project solutions were subjected to a three-level trial in 10 European test sites: the most advanced trials included real-field test with end-users to assess potential for early adoption in four cities: Brussels (Belgium), Canton Ticino (Switzerland), Edinburgh (United Kingdom) and Ljubljana (Slovenia). Beyond providing a journey planner application and the related software platform, the project outputs included theoretical studies (in the form of multimodal routing algorithms), transport studies on the feasibility of an integrated multimodal system, business modelling for potential product roll-out and financial assessment for the 10 project sites.

The RIDE2RAIL project is developing solutions for facilitating the efficient combination of ride-sharing and scheduled public transport services. The project is testing these solutions in demo sites: after successfully testing a "robobus" in Helsinki in late 2021 a new ride-sharing application, called "Driver Companion" with enhanced functionalities was tested in July 2022 in Athens.

The Interreg project SHARE-NORTH aimed at making transport in the North Sea Region more sustainable by developing, implementing, promoting and assessing car sharing, bike sharing, ride sharing and other forms of shared mobility. The project published a 250-page guide ([13]) that covers all the basics of shared mobility, from the different forms and definitions to the impacts and potentials of carsharing, ridesharing, bikesharing, MaaS and mobility hubs, including concrete case studies. The guide and the accompanying webinars aim to help policy makers and other stakeholders by building a solid shared mobility knowledge.

A number of Small and Medium Enterprise Phase 1 instrument (SME-1) projects focus on shared mobility. SHOTL focused on helping transport operators and cities to make a better use of its bus system by replacing low-ridership routes with on-demand shuttles. Since then, it has deployed several successful operations in Europe, achieving a significant increase in demand along with drastic reductions in waiting times. OUITAXI (or WETAXI) developed an app for taxi on demand and taxi sharing services. KAROS developed a smart mobility assistant that accurately anticipates carpool supply and demand. The project is partnering with companies (>500 employees), which partly subsidise the service, in order to offer low-cost and more convenient means of transport to their employees.

4.10 Data driven innovative solutions for traffic management

Mobility nowadays generates huge amounts of data through thousands of sensors, cameras, connected cars, and peoples' mobile devices. These data can be used to extract patterns, optimise and manage mobility and make it more efficient, sustainable and resilient. In fact, big-data provide additional opportunities for analytics, traffic forecasting and dynamic real time routing. At the same time, the Internet of Everything (IoE) is transforming life in urban environments, providing at the same time opportunities for new services and business in mobility and logistics. On the other hand, the large-scale nature of the data and its heterogeneity makes its reuse very difficult. Data standardisation and adequate testing in real environment is paramount for unlocking the capabilities of big-data and IoT. Data pooling can be a significant accelerator for the uptake and scaling of solutions and further collaboration can be fostered to overcome barriers, such as confidentiality due to commercial use of the data by certain stakeholders. Addressing data privacy and creating standards for pooling and sharing in a concerted manner is critical. Finally treating the data governance subjects collaboratively on an EU and cross stakeholder level helps address the subject of mobility data sovereignty, which is also in the best interest of MS and territorial stakeholders.

([13]) https://share-north.eu/the-guide/

Project highlights

The OPTIMUM project developed an information platform supported by big-data analytics and a smart sensing system able to cope with a huge amount of heterogeneous data, which was tested in the cities of Birmingham, Vienna and Ljubljana. Through a mobile app, it facilitated multimodal trips, as well as the integration of proactive information in real time to improve access levels of public transport and allow for a proactive decision making. The project developed a big-data architecture for traffic forecasting and social mining component for identification of situations of interest on transport networks using public input. It also took steps towards data harmonisation.

The SELECT for Cities project developed an open and modular large-scale Internet of Everything (IoE) platform that enables collaboration between departments and cities and testing of IoE services. The project used pre-commercial procurement (PCP) as a basis to stimulate city innovation, which facilitates cities to procure competitive R&D for new innovative solutions from multiple suppliers. This process created products that are actually needed by cities. This PCS was the first in the world to focus on an IoE platform and AI in helping cities bridge the silos in their smart information systems. The project delivered a handbook ([14]) with results, lessons learnt and materials to provide inspiration for cities on how to benefit from PCP.

The SETA project developed a technology for collecting, processing, linking and fusing high-volumes of heterogeneous data from different sensors. The project used advanced neural networks for image analysis, large-scale architectures for data integration, advanced mobility models for tracking mobility via mobiles, and large-scale mobility modelling techniques. The technology has already been adopted by several stakeholders in England and has used it to track (anonymised) data from hundreds of thousands of citizens for health and wellbeing purposes. The technology has also been adopted by the Birmingham City Council to track its 8 000 free bikes. A platform for data and visual analytics has also been developed, which provides city managers with insights into city-wide mobility.

The Track and Know project developed a Big Data processing toolbox that implements data acquisition technology capturing data from heterogeneous data sources. Based on that, a "Complex Event Recognition" toolbox detects complex event occurrences by analysing patterns in simple events. In the mobility sector, the methodology was tested to gain in-depth and accurate crash probability estimation (relevant to insurance), to study the cost-benefit of switching to electric vehicle, by matching charging times and points to drivers' habits, and, for analysing Car Pooling opportunities based on users' common routes and available parking opportunities.

The recent TANGENT project will develop new complementary tools for optimising traffic operations in a coordinated and dynamic way in a multimodality context, accounting for the presence of both automated and non-automated vehicles, as well as for passengers and freight transport. The project will test the efficiency of the developed tools in three case studies: Rennes (France), Lisbon (Portugal), Great Manchester (Unite Kingdom) and a virtual case study in Athens (Greece) using real data from various modes of transport, under different traffic events.

The recent MOBIDATALAB project will propose to mobility stakeholders a replicable methodology and sustainable tools that foster the development of a data sharing culture in Europe. The project will aim to address existing gaps between the demand and supply of data sharing services by developing a cloud-based prototype platform for sharing transport data, to facilitate the access to mobility data in an open, interoperable and privacy-preserving way. Validation will take place in Living and Virtual labs executing co-creation activities.

4.11 Digital tools for transport planning

Travel planning platforms can be considered a key element in future sustainable urban mobility, by enabling robust and efficient multimodal transport. There are various disruptive digital technologies being gradually available, which can bring drastic changes in urban mobility. One important aspect of such technologies is the amount of mobility data generated and collected, by the aggregation of different sources such as crowdsensing and user input, remote sensing and transport and traffic monitoring. These data can be used for routing and traffic optimisation.

While Big Data on mobility begin to accumulate in significant volume, the tools and methodologies to make use of them in a streamlined and accessible manner for the citizen manner are still developing. There is the need for transport modelling and planning tools which can capture and quantify the impact of the different transport

([14]) https://6d3ed0ab-e2de-44c9-b003-85a05bd7fa33.filesusr.com/ugd/a245c2_6dda0eea021c46e6b66616f7bb311141.pdf

modes available in a certain route. Moreover, there are still challenges in providing real-time routes to be taken for a given destination, taking into account traffic, environment, reliability and cost, as well as data pooling cloud platforms which can integrate and fuse mobility data coming from a diverse array of stakeholders.

Research projects in this area focus on integrating the information systems from different sources, in a way that one platform can contain homogenous data which can be used for different purposes. It can be used to optimise travel time to a destination (e.g. airport), while incentivising the use of public transport. The data was also applied in data processing and modelling methods, to allow for the prediction of travelling patterns and to aid in transport planning, as well as travel behaviour modelling.

Project highlights

By Improving the connectivity of people, vehicle and infrastructure, the TIMON project created a cooperative system with integrated traffic and transport management capabilities. By offering efficient planning services, the platform developed in the project provided traffic prediction and multimodal routing system which could reduce traffic, while also allowing for planning of low emission routes for users. The project proposed a cloud-based system which connects data from different types of users, such as cars, pedestrians and cyclists. The system processes this data using artificial intelligence, and provides real-time planning services to the final users. The system was tested in two pilots, in Helmond, the Netherlands, and Ljubljana, Slovenia, which were used to fine tune the system and obtain feedback from users.

One of the obstacles of planning multimodal trips comes from the difficulty in monitoring different platforms for the best route, delays, changes, etc. For this reason, the DORA project developed an application with the purpose of optimising door-to-door journeys for air passengers. A smartphone application (app) was created, where information from different systems is centralised, displaying delays, traffic, best public transport schedules, with access to ticked purchase as well. The app was tested in Berlin and Palma de Mallorca, with high satisfaction from the users.

Within the context of public transport and planning of multimodal trips, there are challenges related to the optimal choice of mode for individuals, as well as the selection of ideal trip. This becomes more relevant depending on the type of trip that a user is making, such as commuting, going out for entertainment, shopping, etc. To be able to provide personalised routes and suggestions for users, the MY-TRAC project developed a Travel Companion application, a platform designed for users and transport operators, with the objective of applying behavioural transport analytics and artificial intelligence, with the purpose of improving passenger experience by taking into account user's habits, usual routes and type of errands. The project ran pilot trials in four European countries (Spain, Greece, Portugal and the Netherlands) with two target groups, public transport operators and users.

4.12 ICT solutions for rail in urban environment

Urban rail transit (e.g. light rail, rapid transit, commuter rail) is an important component of urban mobility and transport. With relatively low lifecycle emissions, electrified rail transport is considered to be key for the reduction of emissions in transport in general, and also in urban areas. It is mostly important as a component of multimodality, where commuters will make part of their urban journey on rail. It is expected that improvements in IT solutions, alongside adaptation of rail communication protocols to platforms dedicated to multimodal services, can improve the quality of service and provide an incentive for modal shift away from more polluting transportation means.

The main research directions for urban rail transit include the deployment of automated and semi-automated trains, to bring reliability, increased capacity and reduced costs. However, the new technologies bring challenges, in particular the need for standardised communication solutions which can link trains, infrastructure and other vehicles. Additionally, methods that can ensure obstacle detection and track intrusion are necessary to ensure safe operations in an urban environment.

Project highlights

Within the Shift2Rail Joint Undertaking, two projects are investigating technologies related to the use of rail in urban environment. The SMART2 project is investigating the implementation of obstacle detection and track intrusion systems, with the purpose of enabling an autonomous obstacle detection for railways. Moreover, the X2RAIL-4 project aims to increase the technology readiness of key technologies in railway signalling, automation and supervision, which goes in line with the Shift2Rail strategy towards a flexible, real-time, intelligent traffic control management and decision support system.

Communication technologies for the railway sector are of crucial importance to guarantee the safe and reliable operation of trains, especially in urban environments, where demand is growing. Within the FAST-TRACKS project, a communication system was developed which addresses the main problems faced by railway system operators (need for flexible architectures, scalable, suitable for different standards e.g. Wi-Fi, 3G and 4G). The research culminated in an innovative integrated communication system, ready to be commercialised, with granted patents as well.

4.13 Innovation in citizen engagement and co-creation of mobility solutions

The selection and path to the uptake of new mobility solutions in cities is often carried out unilaterally, with planning authorities implementing changes without the direct participation of the users. In this sense, participatory design and co-creation of solutions is increasingly becoming known to be beneficial to the acceptance of new technologies, which in turn can bring benefits to the cities and citizens. This is also the approach explicitly recommended in the context of developing and implementing sustainable urban mobility plans.

There are still obstacles to the full implementation of co-creation frameworks in urban mobility. Among them, there is the rigidity of the governance structure, which is usually complemented by top down approaches to changes e.g. a problem is defined, a solution is implemented and then verified. Moreover, citizens are mostly unaware of the practices and investments being proposed in their own urban areas. The same applies for specific social groups for which given solutions are being designed and implemented.

Project highlights

Improving urban mobility and making it more sustainable are linked not only to technological solutions, but also require the participation of users. Involving commuters on tackling the main problems associated with daily mobility is therefore crucial to improve urban mobility. The Cities-4-People project aimed to involve citizens in the co-development and design of local mobility systems. The project partners set-up mobility communities in 5 cities: Budapest (Hungary), Hamburg (Germany), Istanbul (Turkey), Oxfordshire (United Kingdom) and Trikala (Greece). For example, in Budapest, citizens contributed to the design of a transport hub that included e-cars, scooters and bikes, while in Oxfordshire, the project implemented on-demand transport systems, such as shopper services and shuttles. As final conclusions, the consortium outlined the benefits and importance of the co-creation process with citizens.

The Interreg EMOBICITY project sought to improve the uptake of electric vehicles in its partner cities and regions by sharing knowledge and expertise to help them improve their regional, national or local policy framework. The project partners outlined barriers for the uptake of e-mobility in their cities and regions, while seeking for good practices to enable it. For example, one of the project partners established a stakeholder group in Greece, which included key stakeholders such as the Ministry of Environment and Energy, the Ministry of Infrastructure, Transport and Networks, the Hellenic Electricity Distribution Network Operator, with Greek regions and urban areas, to participate in exchange of knowledge within the project. The resulting conclusions from this stakeholder group formed the basis of the new Greek law of June 2020, on Promotion of e-mobility.

With ambitious goals to reduce emissions in urban mobility, city authorities look for policy solutions that can help them achieve such goals. In this context, the Interreg 2050 CLIMOBCITY project set out to explore packages of transport measures that could be adopted to reduce emissions. The European city authorities of Thessaloniki, Plymouth, Leipzig, Bydgoszcz and Almeria were supported by advisory partners on how they could efficiently improve mobility in their cities, through dedicated packages. These included measures such as the expansion of public transport systems, stimulating walking and biking via infrastructure provisions, introducing car-free zones, providing EV-charging point networks, offering shared mobility and Mobility as a Service options, and urban spatial planning schemes, with a different focus for each city.

The TRIPS project focuses on people with disabilities and tries to ensure that their voices are heard when making decisions on mobility solutions. The project developed a co-design-for-all methodology in close collaboration with disabled users and prepared a white paper on accessibility needs in transport planning. The project consortium closely collaborated with several local authorities and non-governmental organisations (NGOs) which advocates for inclusion of people with disabilities into transport planning decision making processes.

4.14 Urban Air Mobility

Urban Air Mobility (UAM) is a new air transport concept for passengers and goods in urban environments, enabled by new technologies and integrated into multimodal transportation systems. Use cases focus on the

commercial transport of people, emergency transport (of passengers or goods) and cargo delivery, the latter focusing mostly on the last mile delivery of goods. Additional use cases include aerial observation including traffic monitoring. Transport takes place in electric vertical take-off and landing (VTOL) aircrafts or air drones remotely piloted or with a pilot on board. UAM promises faster and cleaner mobility (thanks to the electric propulsion) within the city.

The European Union Aviation Safety Agency (EASA) supports UAM through regulatory activities, focusing on airworthiness, operations and pilot licencing, airspace integration and the establishment of the U-Space/UTM (Unmanned Traffic Management) regulatory package which will become applicable early 2023 and will enable the safe integration of Unmanned Aircraft Systems (UAS) operations in urban environment. Much of the groundwork has been carried out through a comprehensive study by EASA on the societal acceptance of UAM operations across the European Union, published in May 2021 ([15]).

In its Sustainable and Smart Mobility strategy, the EC announced its plan to adopt a Drone strategy 2.0 to push forward drones as enabler for the smart and sustainable mobility of the future. The adoption of this strategy is now planned for the fourth quarter of 2022 ([16]).

Challenges for the deployment of UAM include safety and security, noise, user awareness and acceptance. Air space use, air traffic control and the availability of landing sites (vertiports) are also paramount for the successful deployment. Beyond that, UAM should be integrated into the sustainable urban mobility planning process by cities and regions who should best define the fundamental characteristics of the UAM services to meet their citizens' needs ([17]).

Project highlights

Numerous projects under H2020 focus on the deployment and seamless integration of UAM in the existing transport network. Many of the projects started very recently or are still ongoing.

One of the principal issues is the navigation in complex environment, the avoidance of objects and the integration with other airspace users, and the emergency response of the unmanned air vehicle (UAV). An additional issue is that for the urban airspace to sustain high traffic demands, it must be able to allow a shared use, rather than the exclusively assigning parts of the airspace to individual flights. The AMU-LED project focuses on safe flight and navigation towards (a) the safe interaction of UAM with manned aviation and (b) the requirements to fly and navigate safely in complex urban environments (e.g. in presence of high rise buildings and air streams). The project will define, design and deliver a detailed concept of operations and a set of urban air missions. Similarly, the AURORA project will focus on the development of intelligent and fail-safe guidance-navigation-control features by developing an UAV capable of autonomous trajectory generation while detecting and avoiding obstacles (both aerial and ground) in normal and abnormal conditions, and capable of continuous selecting of emergency landing sites and automated landing in case of fatal malfunctioning. The IMPETUS project developed several models for drone testing, focusing on the meteorological prediction, flight planning and capacity management. These models will allow the evolution of U-space services. The METROPOLIS 2 project is developing a unified approach to airspace rules together with flight planning and separation management approaches, in order to determine how UAVs interact with each other, thus allowing a shared use of the airspace under dense traffic. The final concept will be demonstrated in a real-world validation. Similarly, the USEPE project is developing concepts of operations and enabling technologies aimed at ensuring the safe separation of drones (from each other and from manned aviation) in the U-space environment, in densely populated areas.

Communications, navigation and surveillance (CNS) systems are paramount for the safe and efficient UAM operations. The FACT project will apply a performance-based approach that meets the needs of a wide range of airspace users across diverse operations, to update CNS technology and thus increase the safety, security, efficiency and solidity of future air traffic management (ATM) systems. In particular it will address limitations of existing systems focusing on communication technologies that enable the situation awareness of individual users, the strategic deconfliction with other users and the emergency voice link between Air Traffic Controllers and remote pilots. The GOF2.0 project is planning large-scale demonstration of a novel communications architecture in dense urban airspace using current ATM and U-space services and systems.

([15]) https://www.easa.europa.eu/sites/default/files/dfu/uam-full-report.pdf
([16]) https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13046-A-Drone-strategy-20-for-Europe-to-foster-sustainable-and-smart-mobility_en
([17]) https://www.eltis.org/in-brief/news/new-sump-practitioner-briefing-urban-air-mobility

In order for UAM to succeed, air traffic management needs to be integrated within an intermodal transport network. X-TEAM D2D is developing and will validate concepts of operation by considering 2025, 2035 and 2050 time-horizons to enable the door-to-door connectivity using UAM in a multimodal environment.

The FF2020 project focuses on the integrated development of a UAM ecosystem, including (a) a governance model and framework that is both interoperable and scalable, (b) a regulatory framework, (c) a technology agnostic digital toolbox of the geospatial digital infrastructure, (d) an identity framework for operators, drones, authorities and algorithms), and (e) an interoperability framework. The project's solutions will be tested in five living labs during the project, in Eindhoven (the Netherlands), Milan (Italy), Oulu (Finland), Tartu (Estonia) and Zaragoza (Spain).

The CIVITAS ASSURED-UAM coordination and support action (CSA) aims at the development of a set of solutions to assure requirements resulted from integration with manned air traffic management and city mobility upholding UAM acceptability, safety and sustainability. The project will identify the most appropriate technological solutions for UAM implementation with reference to the three time-horizons: 5, 10 and 15 years.

4.15 Electric vehicle charging, grid infrastructure and technology

With the advent of e-mobility, there is great need for vehicle charging infrastructure in urban environments. These can be for use in public transport depots, where electric buses are recharged, but also for private use, such as charging stations at public parking spaces, or for the specific use of logistics operators, which e.g. may recharge the whole fleet at night in private depots. For such cases, there is the need of not only the infrastructure for recharging vehicles, but also digital technologies that can enable smart solutions, such as bi-directional charging and grid energy management. Moreover, understanding citizen behaviour and their motivations, as well as logistics operators' business cases, to switch to electric vehicles (EVs) is also key to a smooth transition.

Challenges for research in EV charging infrastructure and technology are related to the uptake of EVs, as well as the need for infrastructure and the lack of innovative business solutions to drive investment. In this sense, understanding the user perspective and preferences related to EVs and their charging, is an important obstacle to be surpassed. Moreover, testing new charging technologies in actual real conditions is essential to be able to understand the dynamics and difficulties that may arise with large scale deployment. Cost of installation of infrastructure is another challenging topic, with studies on how to alleviate costs through improved business models, optimised operation of infrastructure and combination of charging stations with other services, e.g. parking.

Project highlights

As the number of personal EVs in cities grows, there will be increased need for charging them, with also higher benefits of autonomous charging operations. For this purpose, the Matrix Charging project set out to develop an automated charging system which eliminates the need for charging piles and cords. Within the project, the Matrix Charging technology was developed, from prototype to market ready. It uses a charging pad, which is embedded in parking spaces, and a short connector in the vehicle, which is lowered when the vehicle is parked, enabling charging. The project enabled pilot tests in company fleets and car-sharing services, while also aligning the technology with international standards for autonomous charging.

Light electric vehicles (LEVs), such as electric bicycles, scooters and quads, are often seen as a solution for mobility in urban context, offering more flexibility, with less emissions and traffic. Within this context, the ELVITEN project explored how to integrate LEVs in the cities, taking into account public transport and charging stations. For this purpose, pilot trials were conducted across six European cities: Trikala (Greece), Rome, Bari, and Genoa (Italy), Malaga (Spain) and Berlin (Germany), collecting data and understanding habits of the users, with the purpose of developing not only business models, but also guidelines for city authorities. The project findings also highlight the importance of cost for LEVs, along with infrastructure needs, with the need of a consistent regulatory framework to support their use.

To be able to achieve emission reduction in cities, the uptake of zero emission vehicles must come not only from private vehicles but also from public transport, such as bus fleets, which in turn require efficient charging solutions to be sure that it can operate as effectively as possible. To solve this issue, the CONCEPT project investigated a fast charger that could recharge an electric bus in five minutes. The charger also includes an automated contact system which allows for "opportunity charging" during operation, i.e. the bus can stop for a few minutes along its route at selected locations for a partial charge. Such a method could allow an electric bus to circulate non-stop if needed. The project ran two successful pilot trials, bringing the system to maturity and leading to market rollout and commercialisation.

One of the difficulties related to charging private vehicles in cities comes from the availability of charging stations, especially during busy hours. Moreover, for charging station operations, it is desirable that the stations are continuously in use, maximising profit. Within this context, the MEISTER project consortium developed a system, named Book-n-Park, which allows for drivers to check station availability online, and reserve it on a short notice. The system, which uses a simple to install physical barrier to keep the charger free, is being tested in a pilot trial in Berlin and Malaga.

With the advent of electromobility in the urban environment, the management and optimisation of the energy grid and its usage becomes gradually more important, as well as its interaction with charging vehicles. In this context, the CONNECT project has tackled the peak demand by integrating photovoltaics, battery storage and EV bi-directional charging. To investigate their solutions, the consortium established four pilots around Europe, in Germany, Italy, the Netherlands and Spain, with urban mobility use cases where commuters and shoppers leave their EVs and continue their journey with public transport or bike. In the pilots, focus was given on grid optimisation and stabilisation in a real-life microgrid infrastructure for electric vehicle charging.

On the same topic, two other projects, INTEGRIDY and WISEGRID, have successfully looked into how smart grid solutions can be brought to market and the necessary business models for them. They created toolsets to bring together innovative technologies and help the community to prototype new smart grid business solutions.

Bi-directional charging allows energy to flow to and from an electric vehicle connected to the charger, enabling vehicle to grid (V2X) interaction. This can be used to take advantage of high solar energy output during daytime, or to compensate for high grid demand during peak times. The GROWSMARTER project applied and tested the technology, integrating vehicle and buildings, with on-site renewable energy generation using a photovoltaic plant and energy storage systems, while using a V2X charger. The project consortium developed an energy management system to manage the charge flow, demonstrating that vehicle to grid services are possible.

To be able to encourage the use of electric vehicles in urban environments, it is important to engage key-stakeholders, especially regarding policy making. The Interreg EMOBICITY project has supported such activities, through workshops, study visits and peer reviews, as well as public campaigns and other communication activities. The project consortium has supported policy dissemination on e-mobility at a national and regional levels, and encouraged the increase of knowledge and exchange of experience with policymakers and decision makers. Moreover, the project consortium is developing and providing action plans for the improvement of the policy instruments on the topic, to encourage an increased e-mobility integration.

Noteworthy is also the effort in the context of the ELIPTIC project, which more generally engages in the uptake of electric vehicles in Public Transport, and treated in Stepniak and al. 2022. In this context, it examines both stationary and “in-route” charging infrastructure and automated wiring/de-wiring techniques, and evaluates the potential of multi-purpose use of public transport infrastructure, by offering safe charging opportunities for non-public transport vehicles including cars, taxis and trucks.

4.16 Hydrogen in the urban context

Hydrogen is a promising option for areas of transport where electrification may be difficult, and there are many examples of early adoption by local city buses and taxis. The technologies are mature and much research is being conducted into large-scale deployment of the vehicles to test them in real environments ([18]). The Clean Hydrogen Joint Undertaking is pushing the European technology capability in this area.

Hydrogen projects are more technology centric, with very little urban context within them. In the few projects which also cover hydrogen in the urban context, the tasks are typically not very innovative with limited research elements – e.g., a hydrogen refuelling station is installed and vehicles are allowed to use it.

Projects relevant to public transport (mostly hydrogen fuel cell busses) which have an urban component to them have been covered in Stepniak et al. 2022.

([18]) European Commission, Joint Research Centre, Ortega Hortelano, A., Stepniak, M., Gkoumas, K., et al., Research and innovation in low-emission alternative energy for transport in Europe: an assessment based on the Transport Research and Innovation Monitoring and Information System (TRIMIS), Publications Office, 2021, https://data.europa.eu/doi/10.2760/813147

5 Summary of key achievements

5.1 R&I on a reinforced approach to TEN-T urban nodes

- Urban planning research on the co-design of urban main radial roads, flexible use of kerb space and dynamic allocation of road space.
- Logistics research on synchro modal logistics and cargo flow optimisation.
- Synchro modal logistics and cargo flow optimisation research on dynamic planning and operative optimisation through coordination between urban planners, urban freight logistics actors and citizen engagement.
- Research on Governance and Planning, and promotion of cross-stakeholder collaboration to address simultaneously passenger and freight transport in a holistic and cohesive manner.

5.2 R&I on a reinforced approach to SUMP and mobility management plans

- Development of models and software tools that can help authorities design SUMPs.
- Focus on collaborative actions that bring together different organisations from different countries in a co-creation process.
- Increasing collaboration efficiency by setting up horizontal communication between EU, national and local authorities and raising awareness for best practices through seminars and workshops.
- Integration of logistics and testing of innovative solutions in Living Labs, deployment in lighthouse cities and establishment of networks of cities for further deployment.
- Sustainable Urban Logistics Plans (SULPs) to support and guide logistics in urban areas, as last/first mile logistics.
- Data-driven capacity to identify, track and deploy innovative urban mobility solutions that can feed future policy actions.
- Awareness raising for stakeholders with trainings and workshops, and for citizens through challenges, social media and gamification.
- Mobility management plans are proposed as a tool for stakeholders, to change the mobility culture and habits of target mobility populations, such as employees who commute their company daily, nevertheless few actual implementations are reported until now.

5.3 R&I on monitoring progress – sustainable urban mobility indicators

- Development of policy and governance tools as well as transport planning actions, strongly related to SUMP, that perform a review and analysis of SUMI.
- Governance or planning projects that incorporate SUMIs in their workflow, and align their proper set of KPIs to this framework in order to further promote their adoption.
- Beyond that, projects align with SUMIs for their Sustainability, Environmental and Economic impact analysis, using SUMIs in extension to their SUMP scope in order to provide universal benchmarking for R&I.

5.4 R&I related to a healthier and safer mobility: a renewed focus on walking, cycling and micromobility

5.4.1 Promoting active mobility for all

- Actions to increase attractiveness of everyday cycling and embed cycling into multidisciplinary planning culture.
- Application of a holistic approach to cycling and walking uptake, catalogue best practices and developing methods for walking and cycling modelling, including the health effects.

— Active modes modelling and impact evaluation for reducing congestion and increased travel times, and also by extension pollution and health risks, with the scope to identify and predict active mode flows in urban areas.

— Promotion of active modes by gathering best practices with applications on specific areas (schools, tourism etc).

5.4.2 Technology development for cycling and micromobility

— Development and testing of prototypes of four-wheel, lightweight vehicles within a multimodal trip frame, including business models and insights from user experience.

— Development of microvehicles for older adults or people with reduced mobility.

— Innovation on bicycles, focusing on safety, self-charging bikes and parking infrastructure.

5.4.3 Sustainable urban neighbourhoods

— The upscale of measures on traffic management such as traffic calming, and infrastructural changes to promote public and street space quality and reorganisation to accommodate walking and cycling as a means of improving neighbourhood liveability.

— The positioning of the neighbourhood as the ideal geographical scale for citizen and local business engagement and involvement in the planning decision-making process.

5.5 R&I related to zero-emission city freight logistics and last-mile delivery

— Improvement of multi-level governance models and multi-stakeholder cooperation, new schemes for horizontal collaboration (driven by the sharing economy), urban space management for shared-connected freight and delivery services in cities and re-localisation of logistics activities in multi-modal hubs.

— Use of data driven strategies and tools towards open data services for MaaS providers.

— Improve last-mile delivery using cargo bicycles, Light Commercial Vehicles (LCVs) and novel small sustainable cargo vehicles.

5.6 R&I related to digitalisation, innovation and new mobility services

5.6.1 CCAM in urban environment

— Testing the viability of automated driving functions and other technologies in vehicles on public roads.

— Evaluating the impact of CAVs on urban traffic efficiency, road space requirements and safety.

— Testing of mixed autonomous and conventional vehicle situations, implementing the required physical and digital infrastructures for the proper management of mixed traffic flows.

— Development of techniques for accurate, robust and reliable position estimation for vehicles for safe and efficient operations.

5.6.2 Safe urban mobility

— Development of an alert interface in car displays, to warn drivers when they would be approaching a dangerous crossing, or in accident-prone locations.

— Development of reliable self-diagnostic systems and fail-safe components in software and hardware accounting for possible real-life situations with autonomous vehicles.

— Development of novel road markers to accommodate mixed traffic including connected intelligent transport systems (C-ITS) applications.

— Design of sensor-based detection systems to facilitate detection of cyclists (e.g., at intersections or in a vehicle's blind spot) to increase safety of cyclists in dense urban areas.

5.6.3 Mobility as a Service

— Validation in Living Labs of software enablers, ICT components integrating and enhancing the technological level of a MaaS.

— Development and testing of transport network theories and models to study emerging patterns, transition phases and critical concepts.

— Development of stand-alone digital service, software products and IT solutions for smartphones, also with focus on travel shopping, trip tracking, booking and ticketing.

— Pilot demonstrations in different cities for assessing the success of technology enablers.

— Development of public–policy instruments to help public authorities in supporting MaaS, increasing collaboration between European regions to build trust among key stakeholders.

5.6.4 Shared mobility services

— Assessing the role of car sharing in improving mobility in European urban areas, including new business opportunities to the automotive sector as well as the impact of car sharing on other travel modes.

— Developing a software platform for carpooling in urban and peri-urban areas and developing solutions for facilitating the efficient combination of ride-sharing and scheduled public transport services.

5.6.5 Data driven innovative solutions for traffic management

— Development of a mobility information platform that includes traffic forecasting, supported by big-data analytics and a smart sensing system.

— Deployment of Internet of Everything (IoE) platform that enables collaboration between departments and cities and testing of IoE services.

— Development of heterogeneous data collection and fusion techniques, as well as Big Data processing toolbox that implements those data.

— Develop new complementary tools for optimising traffic operations in a multimodality context, accounting for the presence of both automated and non-automated vehicles, as well as for passengers and freight transport.

5.6.6 Digital tools for transport planning

— Development of a cloud-based cooperative system with integrated traffic and transport management capabilities, including traffic prediction and multimodal routing system.

— Development of a smart-phone application for optimising door-to-door journeys for air passengers.

— Development of a public transport travel companion application for users and transport operators, applying behavioural transport analytics and artificial intelligence, for improving passenger experience.

5.6.7 ICT solutions for rail in urban environment

— Implementation of obstacle detection and track intrusion systems, with the purpose of enabling an autonomous obstacle detection for railways.

— Development towards deployment of key technologies in railway signalling, automation and supervision, for the flexible, real-time, intelligent traffic control management and decision support.

— Development of an integrated communication system to address the main problems faced by railway system operators.

5.6.8 Innovation in citizen engagement and co-creation of mobility solutions

— Involvement of citizens in the co-development and design of local mobility systems to improve the uptake of electric vehicles, explore packages of transport measures that could be adopted to reduce emissions, to improve regional, national or local policy framework.

— Development of a “co-design-for-all methodology” in close collaboration with disabled users to ensure that their voices are heard when making decisions on mobility solutions.

5.6.9 Urban Air Mobility

— Development of concept of operations for the navigation in complex environment, the avoidance of objects and the integration with other airspace users, and the emergency response of unmanned air vehicles (UAV).

— Development of intelligent and fail-safe guidance-navigation-control, including models for drone testing focusing on the meteorological prediction, flight planning and capacity management.

— Developing concepts of operations and enabling technologies aimed at ensuring the safe separation of drones in densely populated areas.

— Development and integration with communications, navigation and surveillance (CNS) and air traffic management (ATM) systems.

— Development of technology agnostic/stakeholder centric governance, regulatory and interoperability framework.

5.7 R&I towards climate-neutral cities: resilient, environmentally friendly and energy-efficient urban transport (with focus on infrastructure for zero emission vehicles)

5.7.1 Electric vehicle charging, grid infrastructure and technology

— Development of an automated charging system (charging pad) embedded in parking spaces, which eliminates the need for charging piles and cords.

— Integration of Light electric vehicles (LEVs) in the cities, taking into account public transport and charging stations, focusing also on development of business models and guidelines for city authorities.

— Investigation of a fast charger that could recharge an electric bus in five minutes.

— Development of a system that allows drivers to check online the availability of charging station, and reserve it on a short notice.

— Integration of photovoltaics, battery storage and EV bi-directional charging and grid optimisation and stabilisation for electric vehicle charging.

— Creation of toolsets for integrating innovative technologies, as well as business models, to prototype new smart grid business solutions.

5.7.2 Hydrogen in the urban context

— Hydrogen projects are more technology centric, with very little urban context within them.

— Development of fuel cells with a higher lifespan and in selected case studies.

6 Conclusions and recommendations

Conclusions are reported separately for the seven action areas of the UMF that have been investigated in this report.

— **A reinforced approach to TEN-T urban nodes**

The current proposed revision of the TEN-T Regulation, in alignment with the new Urban Mobility Framework, underlines the importance of multimodal urban nodes. The conducted works on intermodal connection between long-distance and last-mile freight logistics are essential but the topic still needs to be further investigated. The recently started projects address governance of multimodal passenger and freight zero emission mobility hubs. However, those solutions need to be further embedded into a broader urban transport planning perspective and they would likely require further technological advances. Moreover, the **multimodality of urban nodes** (e.g. park&ride facilities better equipped with appropriate bike parks and recharging and refuelling points for zero-emission vehicles) also requires further research and innovation activities. The final point covers the joint consideration of **passenger and freight flows** in order to optimise the utilisation of the network and means of transport, as well as sharing the available means of transport across different operators to reach increased loads and optimise efficiency. This will have further positive effects, such as decreasing congestion and occupancy of both networks and kerb space, and improving city liveability, and as such should be further investigated.

— **A reinforced approach to SUMPs and mobility management plans**

The concept of SUMPs emerged in 2013 and since then it has been incorporated in EU funded research. The projects assessed in this report focus on many aspects that can help authorities design SUMPs, from **development of models and software tools** to (many) **collaboration** actions. They also introduce new technological developments into SUMPs and avail from Big Data analytics capacities. On logistics, the concept of Sustainable Urban Logistics Plans (SULPs) has been introduced. While SUMPs, and SULPs to a lesser degree, can be described as a mature concept, their uptake is still subject to barriers and disruptions (for example the COVID-19 crisis). Therefore, continuous effort and support for local authorities is necessary to **implement, monitor and continuously refine and adapt SUMPs (and SULPs)** according to the evolution of urban environments, their mobility and logistics needs and solutions in place at each point in time. The recent and ongoing health crisis due to COVID-19 has a direct impact on sustainable urban mobility, and its effects and countermeasures should be further studied. Along with the ongoing energy crisis, these disruptions point out the need for preparedness and the **introduction of concepts of resilience** in SUMPs and SULPs. A continuous effort to centralise, harmonise and analyse the wealth of information and experience from previous programs, and rationalise the tools and guidelines, can be beneficial for the way forward, by **identifying success patterns and similarities between use cases, and distilling best practices**. The involvement at Member State level in order to coordinate the urban mobility actions of cities, ensure their consistency with the European Guidelines as well as to animate a network of cities should be reinforced. Important for future research is the **early adoption of new mobility concepts (such as CCAM and UAM)**, for which little R&I is currently dedicated. A **staged approach** for introducing new concepts considering their development timeline could be necessary. Along with **Living Labs**, it is expected that modern transport **modelling approaches and simulations** (e.g. digital twins and agent-based modelling) will be used to simulate solutions. Concerning mobility management plans, this is certainly an area with potential and of need for further R&I, on their definition, deployment and evaluation since few actual implementations are reported.

— **Monitoring progress – sustainable urban mobility indicators**

The Urban Mobility Framework underlines the importance of monitoring the progress of sustainable urban mobility. For that reason, a pilot project defined and tested **a set of relevant indicators** covering key aspects of urban mobility (e.g. access to mobility services, congestion and delays, road safety, GHG emissions and air quality), and provided a relevant **benchmarking tool**. The pilot covered indicators for 46 cooperating cities. Further works are necessary for a widespread use of the tool among all European cities as it provides a common approach to monitoring and data collection. Finally, indicators reinforce the evidence base for preparing and implementing SUMPs, by tracking changes towards sustainable urban mobility objectives in a given city. A benchmarking tool enables comparison between urban areas and the average record of the participating 46 cities and contributes to identifying best practices. Future initiatives should also include relevant **data dissemination tools, including the related data governance models,** to facilitate the use of collected data by professionals (urban and transport planners, academic

researchers etc.) as well as distilling them into communications destined for the general public. Importantly, implementation of sustainable urban mobility indicators is a subject of the recent Digital Europe Programme (DEP) call ([19]), however details of evaluated proposals are not yet publicly available.

— **Healthier and safer mobility – a renewed focus on walking, cycling and micromobility**

The Urban Mobility Framework puts emphasis on making **active mobility** more popular, safe and better embedded into urban transport planning. Previous European research and innovation projects have achieved positive results related to active mobility promotion and collecting good practices in different urban settings (e.g., commuting to work and to school, tourist destinations etc.). Active mobility and micromobility are part of the guidelines and recommendations in transport planning, however few studies examine the role of active modes in multimodal trips and thus, further works are necessary. The Urban Mobility Framework sees also the potential of **e-cargo bikes** and their role for urban logistics (in particular first/last mile), as a means of achieving both active mobility and zero impact delivery. Their wider uptake may require further technological advances, taking advantage of ICT, geolocation and mobile technologies to further streamline their integration in logistics planning. Similarly, new regulatory and planning developments are necessary to better integrate e-cargo bikes into urban logistics chains and confirm the related economic and environmental benefits. Finally, new developments which facilitate the use of active mobility vehicles by older adults and/or people with reduced mobility could positively influence health and well-being of inhabitants of urban areas. The **safety of vulnerable road users**, like cyclists or users of micromobility vehicles remains one of the main concerns. Although some initiatives have already been carried out in the field (e.g., sensor-based detection systems), further works are needed which would cover technical as well as regulatory needs. In particular, a **common regulation regarding the safety of micromobility users** is of interest, including guidance for local and / or national authorities for its implementation. On a holistic level, **a safe-system** approach is taking shape, as a means of integrating available safety solutions (infrastructure and planning, vehicle safety design, behavioural and social aspects) to address the multi-disciplinary, multi-sector and multi-stakeholder aspects of road safety and approach Vision Zero, necessitating further awareness raising, capacity building and collaboration for its uptake. Certain R&I projects examine the **direct health benefits** for active mobility users, and the indirect health benefits for the urban population through congestion and pollution reduction, and attempt to integrate them into the planning process. This R&I area has further potential for investigation, refinement and diffusion. Finally, promoting citizen engagement and co-creation is particularly appropriate and effective in promoting sustainable and active mobility at the neighbourhood level, as this directly affects their quality of life.

— **Zero-emission city freight logistics and last-mile delivery**

Urban freight and logistics are, as urban mobility in general, in a process of profound transformation, driven by the following drivers. First, the on-demand economy and e-commerce has boomed, and has boosted urban economic activity even during COVID-19 mitigation. This has increased the need for freight throughput, increasing the strain on existing urban networks and systems. Second, in response to the sustainability objectives put forward by the European Union, and the policies, regulations and guidelines stemming out of these objectives, urban freight must improve its efficiency and cut its environmental footprint, diversify its energy resources with less GHG intensive fuels and electrification, and thus contribute also to its resilience against resource scarcity. Finally, for further European transport integration according to the TEN-T corridor paradigm, urban freight has to contribute to the **efficient and fluid integration of urban nodes** in the network thanks to multimodal seamless flows. These strong drivers require a holistic approach, including but not limited to technology development. The systemic complexity of operations and the diversity of actors involved, including cities' authorities and city planners, logistics, supply chain operators and postal services, ICT actors, as well as research and academia (governance, economic, planning and engineering sciences), require an ever-increasing effort in **collaboration as well as observation and knowledge management**. For urban logistics, sustainability will need to be achieved through **flow, asset use and load optimisation**, exploring the potential for railway or waterborne freight transport, and combining it with a modal shift towards more sustainable means of transport, such as cargo bikes and electric vehicles, for first/last mile logistics. In order to achieve this, detailed methodologies for

([19]) https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/digital-2021-cloud-ai-01-prep-ds-mob

demand and flow characterisation, modelling and online optimisation should continue to be developed, refined and scaled-up in order to be able to dispatch efficiently across multimodal networks. This effort should focus on urban specificities, notably responding to both regular and on-demand logistics while minimising the strain on infrastructure and taking advantage of alternative modes (e.g. waterborne or shared with public transport), minimising nuisance and pollution for better liveability, and promoting the use of collaborative and shared storage space and vehicles, and participative platforms to streamline connection between global and first/last mile logistics. This area should be further combined with studies on charging infrastructure and sustainable energy sources to encourage the uptake of zero-emission vehicles for urban transport and logistics. Finally, since several projects share similar ambitions, it is desirable to promote further harmonisation, coordination, and share best practices, for example for the design **of multi-modal hubs**, as well as estimate the environmental, societal and economic benefits of scaled up best practices.

— **Digitalisation, innovation and new mobility services**

For **CCAM in the urban environment**, safety is a priority, especially when there is mixed traffic, and autonomous road vehicles must consider a diverse array of scenarios. For urban rail automation, obstacle detection for safety remains a priority. Beyond that, public engagement and co-creation are important tools to be developed and considered for the acceptance of new technologies. There is **substantial research on MaaS**, with many concepts validated in Living Labs and real cases. Although an overlap in research at high maturity (in pilots) can be observed, this is beneficial, since the complexity of the different environments leads to individual conclusions and additional insights on challenges towards deployment. Similar to **shared mobility and car-pooling**, research is expected to continue availing from the recent developments in ICT technologies and the increase of Big Data analytic capacity. In fact, ICT provides the backbone for future research: from data collection, online optimisation of flows and coordination between stakeholders, to benchmarking and monitoring the systems operation. For **multimodal mobility**, the integration of the platforms of different modes, including exchange of information between two systems, is very important for the development of applications that allow for trip planning. For UAM, there is substantial research that focuses on the safe **integration of UAM** in the urban environment. The research spans many challenges, from defining concepts of operations, to intelligent and fail-safe guidance-navigation-control safe separation of drones, integration with communications, navigation and surveillance and air traffic management (ATM) systems. On-going projects plan to test UAM in Living Labs. With the technologies reaching higher maturity, the challenge will be to integrate them into operational aspects and further test autonomous flight capabilities in a staged approach in real life conditions. **Urban rail transit** is an important component of urban mobility and transport, with research on ICT and on the deployment of automated and semi-automated trains, to bring reliability, increased capacity and reduced costs. For urban rail automation, obstacle detection for safety remains a priority and this could be the focus of future research. Beyond that, **public engagement and co-creation** are important tools to be developed and considered for the acceptance of new technologies, especially as the latter are brought into more mature phases.

— **Towards climate-neutral cities – resilient, environmentally friendly and energy-efficient urban transport (with a focus on infrastructure for zero emission vehicles)**

In the context of the Sustainable and Smart Mobility Strategy, and the EU mission on Climate-Neutral and Smart Cities, a key milestone is to have at least 100 climate-neutral European cities by 2030. Urban mobility is at the heart of this challenge, consequently the Urban Mobility Framework promotes initiatives to facilitate the transition to climate neutrality. To achieve it, urban mobility will require the fusion and upscaling of best practices in all action areas of the UMF, while ensuring synergies with other areas such as renewable energy production and storage. The urban vehicle fleet renewal, a key objective not covered in the other action areas of the UMF, calls for further research and innovation activities related to the uptake of zero-emission vehicles and to increase the availability of efficient, interoperable and user-friendly recharging and alternative fuels refuelling infrastructure in urban areas, considering the different charging needs for freight and passenger vehicles. The previous projects cover a broad range of topics from detailed technological solutions (e.g. fast chargers, charging pads, real-time data for checking availability of charging stations etc.), through grid optimisation or integration of electric vehicles into urban transport systems, to new business models. Nevertheless, further works are still necessary to **develop and test new solutions** as well as to push forward existing ones, in particular to **scale them up and reduce installation and operational costs** (for both, cities authorities and individual users). Importantly, future research and innovation initiatives could take advantage of the Climate-neutral and Smart Cities mission

(European Commission, 2021b), to encourage implementation through large-scale demonstrations. Finally, future studies should also **consider a user perspective and preferences related to EVs and their charging**. Similarly, good practices should be collected in order to provide guidance to city authorities to accelerate the greening of urban transport, including public transport fleets, taxis, shared mobility and rental vehicles, as well as delivery vehicles.

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List of abbreviations and definitions

ABS	Anti-Lock Brake System
ATM	Air Traffic Management
CAV	Connected and Automated Vehicle
CCAM	Cooperative, Connected and Autonomous Mobility
CCC	Construction Consolidation Centre
C-ITS	Connected Intelligent Transport Systems
CNS	Communications, navigation and surveillance
CSA	Coordination and Support Action
DEP	Digital Europe Programme
EASA	European Union Aviation Safety Agency
EFTA	European Free Trade Association
ERDF	European Regional Development Fund
EVs	Electric Vehicles
GHG	Greenhouse gas
GIS	Geographic Information System
ICT	Information and Communication Technologies
IoE	Internet of Everything
IoT	Internet of Things
ITS	Intelligent Transport Systems
LCVs	Light Commercial Vehicles
LEVs	Light electric vehicles
MaaS	Mobility as a Service
MS	Member States
NGO	Non-governmental organisation
PPP	Public Private Partnerships
PT	Public Transport
RFID	Radio Frequency Identification
R&I	Research and Innovation
SaaS	Software as a service
Scan-Med	Scandinavian-Mediterranean
SME	Small and Medium Enterprise
SME-1	Small and Medium Enterprise Phase 1 instrument
SME-2	Small and Medium Enterprise Phase 2 instrument
SNMP	Sustainable Neighbourhood Mobility Planning
SULP	Sustainable Urban Logistics Plans
SUMI	Sustainable Urban Mobility Indicators
SUMP	Sustainable Urban Mobility Plans
TEN-T	Trans-European Transport Network

TRIMIS	Transport Research and Innovation Monitoring and Information System
TRL	Technology Readiness Level
UAC	Urban Consolidation Centre
UAM	Urban Air Mobility
UAS	Unmanned Aircraft Systems
UAV	Unmanned Aerial Vehicle
UIA	Urban Innovative Actions
UMF	EU Urban Mobility Framework
URM	Urban Regeneration Model
UTM	Unmanned Traffic Management
UVAR	Urban Vehicle Access Regulations
V2G	Vehicle to Grid
V2I	Vehicle to Infrastructure
VTOL	Vertical Take-Off and Landing

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