Integrated Urban Mobility Roadmap

Status: Final Draft

Version: 1.3
Date: 20.08.2024
Author:
ERTRAC-ALICE-ERRAC Working Group on Urban Mobility

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Glossary

Acronym	Definition
15mC	15-minute city
2ZERO	Towards zero emission road transport partnership
AFIR	Alternative Fuels Infrastructure Regulation
AI	Artificial Intelligence
AV	Automated Vehicle
AVP	Automated valet parking
CAVs	Connected and Automated Vehicles (CAVs)
CCAM	Connected Cooperative Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
COP	Common operational picture
CSA	Coordination and Support Action
EC	European Commission
EGD	European Green Deal
ENoLL	European Network of Living Labs
ERTRAC	European Road Transport Research Advisory Council
EU	Europe
FP	Framework Programme
FUA	Functional urban area
GDP	Gross domestic product
GDPR	General Data Protection Regulation
GHG	Greenhouse gas
HDV	Heavy-duty vehicle
I2V	Infrastructure-to-vehicle
IA	Innovation Actions
ICE	Internal combustion engine
ICT	Information and Communication Technology
ICT	Information and communications technology
IoT	Internet of Things
ITS	Intelligent Transport Systems
KIC	Knowledge and Innovation Communities
KPI	Key performance indicators
LaaS	Logistics as a Service
LCSA	Life Cycle Sustainability Assessments
LEVs	Light Electric Vehicles

LGBTIQ+	Lesbian, Gay, Bisexual, Trans, Intersex, Queer and additional identities within the spectrum
LUTI	Land Use and Transport Interactions
MaaS	Mobility as a Service
MNM	Mobility Network Management
NEB	New European Bauhaus
NMS	New Mobility Services
ODD	Operational Design Domain
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturer
PED	Positive Energy District
PHV	Private Hire Vehicles
PI	Physical Internet
PT	Public Transport
R&D	Research and development
R&I	Research and Innovation
RIA	Research and Innovation Action
SDG	Sustainable Development Goals
SME	Small and medium enterprise
SSMS	Sustainable and Smart Mobility Strategy
STEM	Sciences, Technology, Engineering and Mathematics
SULP	Sustainable Urban Logistic Plan
SUMI	Sustainable Urban Mobility Indicators
SUMP	Sustainable Urban Mobility Plan
TEN-T	Trans-European Transport Network
TM	Traffic Management
UCC	Urban Consolidation Centres
UMWG	Urban Mobility Working Group
UVAR	Urban Vehicle Access Regulation
UX	User Experience
V2G	Vehicle-to-grid
V2I	Vehicle-to-infrastructure
V2X	Vehicle-to-X
WG	Working Group
WHO	World Health Organisation

1 INTRODUCTION

1.1 Background

ERTRAC, the European Road Transport Research Advisory Council, represents a diverse range of road transport stakeholders from the private and public sector, including industry, academia, and public authorities from the local, regional, national, and European level. As ERTRAC involves multiple stakeholders, it is unique in that it can offer a comprehensive and integrated perspective on road transport-related issues with the aim to better coordinate public and private research and innovation activities, to offer detailed recommendations on how to do so and which topics to prioritise. ERTRAC delivers roadmaps for cross-cutting research that serve as input to future European and national transport research and innovation programmes.

Taking into account the inherently integrated, multimodal and multi-stakeholder nature of the urban transport ecosystem, the ERTRAC Urban Mobility Working Group adopted a collaborative approach and joined forces with the European Technology Platforms ERRAC (rail) and ALICE (freight), to form a cross-ETP Working Group on Urban Mobility.

Urban mobility constantly evolves along with technological and non-technological progress, economic changes, societal and environmental challenges, trends and behaviours, and actions and reactions to the marketplace. There is common agreement that urban transport, for both passengers and goods, should be environmentally friendly, convenient, accessible, affordable, and resource-efficient for all.

In order to meet the challenges of today and prepare for a more sustainable and well-balanced mobility system in the future, the ERTRAC urban mobility roadmap requires periodic updates. This version serves as an update to the Integrated Urban Mobility Roadmap of 2017. It aims to present a comprehensive and integrated perspective on urban mobility, identifying research and innovation needs and laying the groundwork for the future - towards optimising urban mobility systems and addressing related challenges ahead.

The roadmap brings the perspectives of experts and different types of stakeholders, thus representing a holistic perspective on the urban mobility system, and integrates the learnings of thematically focused roadmaps and papers produced by the Working Group over the past years.

Updating and integrating the previous urban mobility roadmaps and documents also includes an appreciation of research and innovation projects in the urban mobility field that have been funded so far through the Horizon 2020 and Horizon Europe Research and Innovation Framework Programmes and the extent to which they addressed research, innovation, and deployment priorities identified in earlier ERTRAC urban mobility documents.

1.2 Scope

The roadmap examines all the aspects of the complexity of urban mobility systems, considering transport users, operators, vehicles, modes, infrastructures, services, the digital transition, policy and governance. It considers trips by public, shared, and private transport, motorised and active. It also examines the connections between urban, peri-urban, and rural areas and the interface with interurban and long-distance mobility services. This roadmap takes into account the dichotomy between mobility demand and place demand. It aims to improve the relationship between urban mobility and land use planning, with actions to encourage a more sustainable mobility system with increased use of active modes, public transportation and shared mobility.

Chapter 2 outlines research and innovation methodologies and covers cities and districts as living labs, transferability and capacity-building approaches, impact assessment of Research and Innovation (R&I) efforts, and aspects of international cooperation.

Chapter 3 addresses policy drivers and considers climate neutrality, environmental policies, land-use and transport interaction, and the just and digital transition.

Chapter 4 examines research needs, priorities and milestones with regard to frameworks and enablers for the urban mobility transition. This includes Sustainable Urban Mobility Plans (SUMPs), Sustainable Urban Logistic Plans (SULPs), Artificial Intelligence (AI), and modelling tools to improve policymaking and service design, governance and regulations, co-creation, and public involvement.

Chapter 5 provides an overview of research needs, priorities and milestones for urban mobility solutions and services. Sub-chapter 5A examines infrastructure-related solutions – the built environment, mobility networks, mobility data, and energy infrastructure for clean fuels and vehicles. Sub-chapter 5B covers service-related solutions – New Mobility Services (NMS), next-generation Mobility as a Service (MaaS), and urban freight and logistics. Sub-chapter 5C covers management-related solutions – demand management, integration of urban mobility and network management, and integration within overall European transport chains. Sub-chapter 5D covers integrated solutions, including infrastructure, services, and management. This includes active travel, LEVs (Light Electric Vehicles) and new concepts for urban use, as well as advanced automation in an urban context.

This document covers the current state of play and a future outlook, proposing a set of key recommendations for research and innovation priorities.

1.3 Complementarity between ERTRAC roadmaps

ERTRAC's mission is to provide a framework to focus public and private resources on the necessary research & innovation activities for road transport in all its forms. The present document, carried out by the UMWG, addresses urban mobility and its many ongoing challenges and thus feeds on previous work developed by ERTRAC.

This roadmap builds upon previous ERTRAC Roadmaps, most notably those produced by the ERTRAC-ERRAC-ALICE Urban Mobility Working Group (UMWG) from 2017 to 2023. In addition, it considers the

societal, economic, and environmental changes that have occurred in recent years and their impact on urban mobility. As such, this version is an integrated and extensive update of the following UMWG roadmaps:

- **New Mobility Services Roadmap (2021):** This document addressed shared and new mobility services and their role in the sustainable urban mobility ecosystem, defining research needed to boost their benefits and avoid negative externalities. Three main types of New Mobility Services (NMS) were considered: micromobility, Mobility as a Service (MaaS) and Automated Vehicles (AVs).
- **Urban Mobility Resilience Roadmap (2021):** This document was published during the COVID-19 pandemic, at a time characterised by new challenges and a need to rethink urban mobility, while making it more resilient. Its main goal was to prepare the urban mobility system for future shocks by outlining the research needed to plan, enable and provide a resilient mobility system.
- **Integrated Urban Mobility Roadmap (2017):** This document addressed the entire urban mobility system (all types of users, modes, infrastructures and services) to define research needs, priorities, and milestones.

Findings from discussion papers elaborated by UMWG on topical issues, such as the **15-minute city** and **Light Electric Vehicles,** have also been incorporated.

Although the UMWG addresses urban mobility specifically, insights from other ERTRAC WGs have also been taken into account in view of their relevance for and complementarity with this present roadmap, more specifically the:

1. **Safe Road Transport Research Roadmap Towards Vision Zero: Following the Safe System Approach (2021):** This document addresses all aspects related to road safety and security, including but not limited to the safety of people walking, cycling, and other street users in urban contexts.
2. **Safe Road Transport Research Priorities for 2025 – Safer and More Sustainable Mobility for All (2023):** This paper describes R&I needs proposed to be prioritised for the "Climate, Energy and Mobility" Work Programme 2025 of Horizon Europe.

- **Connected, Cooperative and Automated Mobility Roadmap (2022**): This roadmap provides a joint stakeholder view on the long-term development of Connected, Cooperative and Automated Mobility in Europe, including in urban settings.
- **Mapping of Technology Options for Sustainable Energies and Powertrains for Road Transport Towards Electrification and other Renewable Energy Carriers (2022).** This document presents the perspective of the research community over the different technology options to address the environmental and energy challenges for road transport.

The roadmap is an outcome of the cooperation of ERTRAC, ERRAC and ALICE. Also, these ETPs have recently published roadmaps that inform this document:

- **ALICE Roadmap to Physical Internet[1]:** This document is a comprehensive roadmap towards the Physical Internet (PI). The roadmap sketches a path from now to 2040 showing important milestones, required technologies, and first implementation opportunities for the PI.

[1] https://www.etp-logistics.eu/wp-content/uploads/2022/11/Roadmap-to-Physical-Intenet-Executive-Version_Final-web.pdf

- **Rail Strategic Research and Innovation Agenda[2]:** This Strategic Research and Innovation Agenda (SRIA) for the railway sector in Europe outlines how a new programme of technical and operational innovation can transform the railways' contribution to mobility in Europe by addressing the needs of railway users, the economy, and society while protecting natural resources and the environment.

1.4 Policy background and high-level targets

This roadmap is set within the EU policy frameworks that relate to Urban Mobility. The high-level policy affecting urban mobility is the European Green Deal[3] (EGD): this principal EU strategy lays down the ambition of no net emissions of greenhouse gases by 2050. Economic growth would be decoupled from resource use, and no person or place should be left behind in this transition.

The Green Deal sets the basis for sectoral strategies, i.e. the "Sustainable and Smart Mobility Strategy"[4]. The key objectives of this document are to increase the uptake of zero-emission vehicles, make sustainable alternative solutions available to the public and businesses, and support digitalisation and automation, thus improving connectivity & access.

The Sustainable and Smart Mobility Strategy, in turn, forms the basis to formulate a more concrete new European Urban Mobility Framework[5]. This framework helps the EU meet its 2050 climate target and encourages EU countries to develop urban transport systems that are safe, accessible, inclusive, affordable, smart, resilient, and emission-free.

The New EU Urban Mobility Framework describes outcomes that can be supported by Research and Innovation activities:

- A more ambitious approach **to sustainable urban mobility planning** and related indicators. This links with **new requirements** put forward in the revised Trans-European Transport Network (TEN-T) Regulation **for the largest 431 EU cities** on the TEN-T network to adopt a sustainable urban mobility plan (SUMP) and collect relevant data;
- Stronger action to create climate-neutral cities. Action points cover making **urban transport** resilient, environmentally friendly, and energy-efficient, as well as identifying zero-emission solutions for **urban logistics;**
- New measures to promote **active mobility** and protect **vulnerable road users;**
- More effective **zero-emission city freight logistics and last-mile deliveries;**

[2] https://errac.org/publications/rail-strategic-research-and-innovation-agenda-december-2020/
[3] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[4] https://transport.ec.europa.eu/transport-themes/mobility-strategy_en
[5] EUR-Lex - 52021DC0811 - EN - EUR-Lex (europa.eu)

- Guidance on passenger transport-on-demand **(taxis and Private Hire Vehicles (PHV) with drivers)** so it can become more sustainable and deliver efficient services to citizens while helping maintain the single market to function smoothly and addressing social and safety concerns;
- Accelerate digitalisation and innovation by incorporating urban mobility in the work on the **provision and processing of commercially sensitive data** for multimodal digital mobility services such as Mobility as a Service (MaaS) applications, and on a common European mobility data space to facilitate access to and sharing of mobility data;
- Digital solutions to enable more effective and user-friendly **low-emission zones and other types of urban vehicle access regulation.**

Since the publication of the three strategic documents mentioned above, several legal frameworks have been established that impact the urban mobility innovation pathway. The following important milestones are set in the framework of, among others, the Alternative Fuels Infrastructure Regulation (AFIR), the ITS Directive and its respective mandates, the TEN-T Regulation, and the EU Automated Driving Systems Regulation.

- 2025 – First milestone AFIR
- 2025 – ITS directive: data creation mandates start
- 2027 - 431 Urban Nodes on the TEN-T need to have a Functional Area Level SUMP
- 2027 – Second milestone AFIR – 1st milestone for urban nodes
- 2028 – ITS directive: historic data availability
- 2029 – Final milestone EU Automated Driving Systems Regulation (e.g. Automated Valet Parking)
- 2030 - 440 Urban Nodes: requirement to have an intermodal passenger interchange
- 2030 – AFIR completion (core and comprehensive network)
- 2030 – 100 Climate neutral and Smart cities (Mission) reach climate neutrality
- 2030 – cleaner ambient air (limit values to be attained)
- 2035 - 440 Urban Nodes: requirement to have an intermodal freight interchange
- 2035 – Phase out of sales of internal combustion engines (ICEs) for passenger cars (with caveats)
- 2035 – Zero Emission city buses (with caveats)
- 2050 – Zero air pollution by 2050
- 2050 – EU as the first climate neutral continent

As the period that the roadmap covers coincides with the first phase of the pathway to climate neutrality, it is worth keeping these policy milestones in mind, understanding that R&I could contribute to achieving the objectives, but also could build on what has been achieved through regulation and legislation.

1.5 Cities in transition

In the EU, cities occupy only 4% of the land area but are home to 75% of its population. In addition, cities consume more than 65% of the world's energy and are responsible for over 70% of global CO2 emissions[6]. Moreover, projections show that cities are expected to keep growing at an unprecedented rate, with an estimated two-thirds of the world's population expected to live in cities.

Eurostat expects the number of people living in metropolitan areas to continue to grow[7]:

- The number of inhabitants living in capital city metropolitan regions is projected to continue rising each year until 2050.
- Projections suggest that the number of inhabitants living in metropolitan regions (other than the capital) will also grow each year through 2040, after which there will be a modest decline.
- By contrast, the number of inhabitants living in non-metropolitan regions is projected to fall each year, with the rate at which their population declines accelerating from 2035 onwards.

The growing number of inhabitants in locations that are limited in the availability of space that can be dedicated to mobility puts further requirements on space efficiency of mobility as well as modal share. However, it is important to note that urban areas in the EU vary significantly in terms of their characteristics, sizes, populations, levels of urbanisation, population density, and connections with surrounding metropolitan areas, cities, suburbs, large and small towns, and urban neighbourhoods. These differences and local relationships lead to varying starting points, policy frameworks, and recommendations for urban mobility.

Therefore, cities have and will continue to have a central role in addressing a number of posed challenges as the current climate crisis pushes forward the need to rethink lifestyles and ensure liveability. Many of the EU policies respond to these challenges but also recognise the importance of cities, aiming at bringing concrete solutions and delivering tangible results in many fields. Moreover, in the urban scenario, mobility is of utmost importance to improve health and overall quality of life by addressing air quality, road and transport safety, reducing congestion, and other aspects.

In its present state, transportation has accounted for many negative externalities, such as air and noise pollution, CO2 emissions, congestion, and road crashes. However, it is also a key enabler of economic development, employment, social interactions, and inclusion. Therefore, the challenge is how to improve mobility systems, reducing its adverse consequences while boosting benefits. Over the past years, a change in urban mobility has become evident, transitioning from a car-dependent system to a more multimodal approach, with strengthened PT, and fostering active modes.

[6] Climate-neutral and smart cities - European Commission (europa.eu)
[7] Urban-rural Europe - demographic developments in cities - Statistics Explained (europa.eu)

The advance of digital technologies can support a gradual shift from ownership-based to service-based solutions, supporting change in the mobility landscape with the uptake of MaaS, the digitalisation of mobility, and the advent of New and Shared Mobility Services such as LEVs or micromobility. Furthermore, changes in consumption patterns and digital commerce have altered the mobility of goods in cities and have further increased pressure on urban space.

With the transport sector employing 5 million people in the EU alone[8] and contributing to around 5% of the EU's GDP, mobility and transport strongly impact EU citizens' daily lives. How to adapt mobility and cities to new challenges of climate change, economic developments, social inequalities, and recurring crises will determine liveability and readiness for the years to come.

Road congestion currently costs €110 billion annually, and in the latest Eurobarometer survey of citizens on mobility and transport (2019), 52% of respondents use a car on a typical day, although in some countries (Ireland, Cyprus, Luxembourg, Malta and Slovenia), this figure is higher than 65%. Nevertheless, the Eurobarometer also shows that European citizens are becoming more environmentally conscious with 6 out of 10 declaring to be ready to switch to more environmentally friendly modes[9]. Thus, many European regions and cities face the challenge of improving and responding to the demand for better access to sustainable mobility infrastructures and services.

In parallel, the outbreak of the COVID-19 pandemic also showcased cities' fragility in responding to certain situations. Challenges such as transport capacity during social distancing, a sharp decrease in PT demand accompanied by increased private transport use, and unequal distribution of public space between modes became more apparent.

Given the many challenges urban mobility faces, action is required. Research must be oriented in the right direction to achieve more sustainable, resilient, smart, and inclusive urban mobility.

Through the research and innovation methodologies and policy drivers described in this document, the roadmap will identify research needs and priorities and outline expected outcomes for urban mobility that will support cities in transition.

[8] Social provisions - European Commission (europa.eu)
[9] Key figures on European transport 2022 edition - Eurostat KS-07-22-523-EN-N.pdf (europa.eu)

2 POLICY DRIVERS

The Urban Mobility Working Group actively supports the notion of policy-led Research and Innovation (R&I), emphasising the integration of R&I with policy objectives. A prime example of this approach is the EU Climate Neutral Cities Mission, which exemplifies the alignment of research initiatives with broader policy goals. The preceding chapter outlines the EU policy framework that cities must adhere to over the next 15 years, a timeline that extends beyond the upcoming Framework Programme (FP) for R&I and into the subsequent one. Given that urban mobility research is intrinsically linked to deployment, the research and innovation initiatives proposed in this document are designed with high Technology Readiness Levels (TRLs), ensuring they are close to deployment. Consequently, the next chapter will provide a detailed elaboration on several key policy fields.

Over the past years, the EU has played a leading role in facing the challenges posed by the climate emergency, pushing forward different policies addressing mobility, societal needs, and the emergence of new technologies. Since the completion of ERTRAC's Integrated Urban Mobility Roadmap of 2017, policy goals have become more ambitious, as described above (section 1.4). Considering that transport accounts for a quarter of greenhouse gas (GHG) emissions in Europe and is the main cause of air pollution in cities[10], it is clear that urban mobility faces many challenges in the coming years, to achieve these ambitious goals for cleaner cities.

In addition to decarbonisation and emission reduction, environmental and sustainability concerns have also resulted in a debate around new urban planning approaches. Proximity-based planning, improved accessibility, human-centred design, and reduced car dependency are some of the guiding concepts behind these new approaches. Embracing these concepts will inevitably bring about transformative changes to land use planning and, consequently, to urban mobility.

The recent years have also witnessed the rise of technology in an increasingly digital world. While some new technologies have become established and accepted, others are novel and are still to be scaled and further deployed, requiring a smart regulatory framework to avoid negative impacts on policy goals, especially in a sector such as urban mobility. For instance, Artificial Intelligence's role in transport is still to be defined.

Achieving real change and fulfilling sustainability goals requires a transition to a greener economy. However, it is vital that this transition is just and equitable and addresses not only environmental challenges but also digital transformation. The green and digital twin transition will require the adaptation of urban mobility both from a user perspective and a service provider role.

This chapter covers critical aspects of today and tomorrow’s urban mobility, delving deeper into the policy drivers mentioned. Although these topics may seem independent at first glance, they are, in fact, deeply intertwined and thus approached in an integrated manner.

[10] Chapter 1 - Climate change mitigation — European Environment Agency (europa.eu) and European Climate Risk Assessment — European Environment Agency (europa.eu)

2.1 Environmental policies

Becoming climate neutral is one of the EU's main goals set out in the Green Deal. This long-term goal comes with a number of challenges, many of which are linked to transportation. With transport representing around 25% of carbon emissions and road transport accounting for about 70% of that share, urban mobility plays a crucial role in addressing climate change.

Moreover, the climate is changing, and extreme weather events, such as storms, floods, droughts, and heat waves, will become more frequent. Related impacts have major consequences for society and require specific interventions to maintain safety and accessibility (IPCC, 2021). Thus, in addition to its role in reducing emissions, urban mobility must account for how it can be influenced by climate change and its impacts, as well as how it should respond.

In the path to climate neutrality, it is important to consider mitigation and adaptation. Climate adaptation refers to adapting society to the effects and consequences of a changing climate, i.e. taking measures to prepare for and adapt to both the current effects of climate change and expected effects in the future to moderate harm or exploit beneficial opportunities. Mitigation refers to transforming society to reduce greenhouse gas emissions or enhance the sinks of greenhouse gases. Regardless of the success of mitigation efforts, climate change is expected to persist due to the natural system's inertia, necessitating adaptation measures. Therefore, climate mitigation and adaptation should be pursued in tandem, as the necessity for adaptation can create opportunities for mitigation, and vice versa.

Within the urban mobility context, different lines of action have been adopted to pave the way to climate neutrality. While considering CO2 emissions, there has been an ongoing shift from fuel-consuming vehicles to carbon-free or carbon-neutral options, such as electric vehicles, hydrogen, or synthetic fuels. This transition has also affected buses, trams, and trains, with the aim that carbon-neutral transport could effectively reduce GHG emissions while providing alternatives to cars [11]. Electrification, especially, has taken on a central role in decarbonising transport. Implementing stricter emissions standards has aided this process. Lowering pollutant emissions along with emphasising "Real Driving Emissions" has also boosted the reduction of GHG emissions in the transport sector [12]. Moreover, the literature has also shown that rebound effects can occur, resulting in an increase in road transport demand following improvements in fuel efficiency. Recognising these rebound effects is vital for selecting the most suitable policy instruments.

Policies such as Low Emission Zones and Zero Emission Zones have been implemented to reduce pollution in urban settings and bring benefits to the environment and health. Along these lines, active modes have been encouraged, highlighting their many positive consequences on physical and mental health and the environment.

Moreover, reducing reliance on cars has been recognised as pivotal, involving the enhancement of PT and promotion of active mobility. This entails improving and greening infrastructure and service accessibility, as well as making them "smarter". Smart mobility has gained prominence, and along with the change from ownership-based solutions to service-based solutions, there has been wide adoption of shared mobility options and Mobility as a Service. Nevertheless, it is crucial that these new mobility options

[11] Research and innovation paving the way for climate neutrality in urban transport: Analysis of 362 cities on their journey to zero emissions - ScienceDirect
[12] ERTRAC-Fuels-Powertrains-Research-Needs-Mapping-Final-Version-December2022.pdf

align technologies, innovations, economics, and broader societal and environmental objectives to avoid conflicting and unbalancing interests.

Likewise, the emergence of Artificial Intelligence in daily life, along with ongoing digitalisation, has also brought to light the negative externalities of using such new technologies. It is important to carefully assess how digitalisation, AI, and other emerging technologies can contribute to urban mobility in achieving climate neutrality without causing adverse outcomes, be they environmental, social, or otherwise, that could undermine the intended benefits.

Air pollution continues to be an issue across the EU, being the largest environmental health risk in Europe. As the EEA states[13]: It is common to have air pollution levels that are higher than the latest World Health Organisation (WHO) recommendations.

- In 2021, 97% of the urban population was exposed to concentrations of **fine particulate matter** above the health-based guideline level set by the World Health Organization.
- An estimated 1,200 deaths in people under 18 years could be caused by air pollution from different sources every year in EEA member and collaborating countries.
- Data from 2021 show that central-eastern Europe and Italy reported the highest concentrations of particulate matter, primarily due to the burning of solid fuels for domestic heating and their use in industry.
- All EU countries reported **levels of ozone and nitrogen dioxide above the health-based guideline** levels set by the World Health Organization.

Air pollutants can originate from various sources, with road transport being a considerable contributor. However, there are indications of improvement, attributable to the implementation of cleaning fleets and policies by local authorities. Emerging pollutants are now being closely monitored, prompting cities to take action.

It is also important to emphasize that urban mobility does not happen in insolation but within urban environments. Spatial planning and the built environment inevitably impact mobility. The planning principles of the 20th century have become outdated and contrary to climate adaptation efforts. New urban models have been proposed in recent years to reduce both the built environment's environmental impact and the need for travel and its negative externalities, such as Transit-Oriented Development or proximity-based planning. Re-shaping cities is pivotal for achieving climate neutrality. In this manner, the European Mission Climate-Neutral and Smart Cities aims to deliver one hundred climate-neutral and smart cities by 2050 through different actions relating to zero-emission mobility or clean-energy districts[14]. It focuses on fostering innovation, sustainability, and digitalisation to transform urban areas into environmentally friendly, efficient, and technologically advanced spaces[15].

[13] Air pollution | European Environment Agency's home page (europa.eu)
[14] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en
[15] https://research-and-innovation.ec.europa.eu/system/files/2021-09/cities_mission_implementation_plan.pdf

In addition, adaptation measures such as nature-based and blue and green solutions[16] can generate positive synergies such as the creation of greener cities and the use of green spaces as reservoirs for rainfall, shade in the summer and the promotion of ecosystem services. Thus, to manage both mitigation and adaptation, nature and its dynamics need to be much better integrated into urban, peri-urban and rural spatial mobility planning and how to reconcile mobility into this.

All in all, adapting urban mobility to climate change involves implementing strategies and technologies that reduce emissions, enhance resilience, and promote sustainable transportation options. It also requires a multifaceted approach involving government policies, technological advancements, and changes in individual behaviour. Therefore, multi-level governance, institutional capacity, trust, and social justice considerations in the system (infrastructure, energy supply, human behaviour, etc.), along with spatial planning, risk management, nature conservation, business and society, must all be addressed in conjunction. There is also the need for continued investment in collaboration and co-creation between multiple actors, including society. Explorative and co-creative processes have gained relevance as research methods for learning, development, and implementation. For instance, new European initiatives such as the New Urban Bauhaus bring innovative approaches with storytelling and artistry as part of the process to reach a common vision of a desirable urban future and ways forward. By promoting sustainable transportation options, reducing emissions, and enhancing resilience, cities can mitigate their contribution to climate change and create more liveable urban environments.

The resilience of infrastructures not only against climate change but against physical, cyber, and hybrid threats, e.g., natural hazards, terrorism, pandemics, accidents, insider threats, and state-sponsored hybrid actions, needs to be considered. Two recent EU directives, the CER Directive and the NIS 2 Directive, which entered into force on 16 January 2023[17], deal with these broader aspects of resilience and can support the path to climate adaptation and neutrality.

In addition to becoming climate neutral, the EU is also committed to the precaution, prevention and rectification of pollution at its source. What is more, environmental policy is becoming increasingly more important in policymaking, with the EGD, the first European Climate Law, being launched in 2019 [18] and the EC "Fit for 55" policy packages. As important as cutting GHG emissions is, as per the amount of effort done in this direction, reducing all types of pollution is also key.

These issues are central to urban mobility. With many efforts to decarbonise transport relying on alternative energy sources and fuels, Life Cycle Sustainability Assessments (LCSA)[19] should have a more prominent role in mobility systems so that climate neutrality can be achieved. Additionally, the management of waste generated from urban transport must also be considered to avoid illegal exportation or improper disposal that could be a hazard to the environment and communities alike. This is also crucial when considering the rise in LEVs in cities, where improper materials, devices, use, and tampering trends might lead to increased waste, pollution, and safety risks.

It is also worth further examining other consequences of electrifying urban transport. While GHG emissions may be reduced, it is also necessary to target other environmental issues beyond decarbonisation such

[16] https://knowledge4policy.ec.europa.eu/glossary-item/green-blue-infrastructures_en
[17] https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3992
[18] https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_en#:~:text=The%20EU%20aims%20to%20be,action%20under%20the%20Paris%20Agreement%20
[19] https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/life-cycle-sustainability-assessment/

as brake and tyre emissions, and contributions to externalities such as the use of urban space, safety, and congestion. There is also an open question on how electrification will influence car ownership and use in order to reduce the impacts on the environment and quality of life.

- Zero pollution: Current research explores how the green transition will prompt the adoption of new materials for road construction and influence emissions from the evolving vehicle fleet. This includes assessing the impact of hazardous materials on public health and regulating their use. Previous studies have led to significant changes like the ban on leaded fuel and regulations on diesel sulphur levels. Current focus areas include understanding how road traffic and urbanisation contribute to air, soil, and water pollution, particularly through inadequate stormwater management. The rise of electric vehicles, which are heavier due to battery weights, increases the challenge of particles and emissions from tyres.
- Noise: Road traffic noise poses a growing health risk, primarily stemming from tyre-road interaction. Various mechanisms contribute to this noise, linked to pavement design. Efforts to comprehend and mitigate these mechanisms are crucial. Multifunctional solutions such as enhancing urban greenery, air quality, water management during heavy rain, and providing shade in heat are imperative.
- Circular economy: Using alternative and local materials reduces virgin material use, fostering a circular economy and resource optimisation. Assessing their quality and technical properties ensures safe usage. Sustainable mobility necessitates integrated strategies for energy-efficient, climate-smart technologies and production. Implementing solutions to enhance energy efficiency and promote sustainable energy transition is crucial for efficient reuse and recycling with minimal environmental impact. The circular economy demands more ambition and transformative change in the entire life cycle of public transport systems. This approach involves internalising externalities - such as the impact of embodied carbon and ecosystems on battery manufacturing - into the specific scope of planning and decision-making of the different transport stakeholders along the value chain. To this end, circular economy calls for moving from an "extract-use-throw" to an "avoid-extend-transform" model. Actions in this field involve not only technical/technological advancements but also market, policy, and organisational culture actions. The circular economy can contribute to closing the loops of materials and resource flows and to fostering more balanced production and consumption patterns in the sector.

2.2 Integrated policies for land-use and mobility planning

Urban mobility is intrinsically linked to urban space and planning, meaning there is an interaction between land use and transportation. Urban ecosystems represent around 22% of the land surface of the Union and constitute the area in which a majority of the citizens live[20]. LUTI (Land Use and Transport Interactions) planning has been addressed previously by the ERTRAC UMWG in the Land Use and Transport Interactions Integrated Research Initiative document (2013)[21], where research lines were defined. The issue has become the subject of EU legislation with the Nature Restauration Law[22]. It defines urban green spaces as to “include urban forests, parks and gardens, urban farms, tree-lined streets, urban meadows

[20] Regulation of the European Parliament and of the Council on nature restoration EUR-Lex - 52022PC0304 - EN - EUR-Lex
[21] ERTRAC Integrated research initiative « Land use and transport interactions » June 2013
[22] Regulation of the European Parliament and of the Council on nature restoration EUR-Lex - 52022PC0304 - EN - EUR-Lex

and urban hedges, and provide important habitats for biodiversity, in particular plants, birds and insects, including pollinators. They also provide vital ecosystem services, including natural disaster risk reduction and control (e.g. floods, heat island effects), cooling, recreation, water and air filtration, as well as climate change mitigation and adaptation." The mobility system is set in this context. This new legislation will influence urban land use and the allocation of public space by mandating that there should be no overall reduction in urban green space and urban tree canopy cover by 2030 across all cities, towns, and suburbs. The total area of green urban spaces in cities, towns and suburbs should grow to 3% by 2040 and to at least 5% by 2050 of what the total area of cities, towns and suburbs was in 2021.

In the latter half of the 20th century, there was a rise in car usage, leading to urban planning characterised by the separation of spatial functions as outlined in the Athens Charter, monofunctional neighbourhoods, long distances, and car dependency. However, new urban planning approaches have emerged in recent years, with close ties to transportation planning. The widely endorsed New Leipzig Charter[23] prominently articulates this turn to diverse and multi-functional "cities for the common good". Also, proximity- and time-based planning, also known as **chrono urbanism**, has become increasingly popular, embodied by the rise to prominence of the 15-minute city (15mC) model. The model is based on the idea that every citizen should be able to access their daily needs (e.g., living, working, commerce, healthcare, education, and entertainment) within a 15-minute walk or cycle ride. Time-based planning considers that quality of life decreases as time spent on transportation activities, like commuting, increases. Therefore, land use should deliver diversity, density, proximity, and digitalisation, the four pillars of the 15mC concept, to reduce the need for time-consuming commuting and long displacements in daily life.

For more balanced land use, the four pillars are defined as such:

- Diversity, addressing the need to foster mixed-use planning and also social and cultural diversity within neighbourhoods;
- Density, as in finding the optimal people per km^2 in order to balance economic, environmental and social sustainability;
- Proximity, both temporal and spatial, to reduce commuting time and its economic impact and promote close-knit communities and social interaction;
- Digitalisation, aligned with the Smart City concept, makes it possible for the three previous pillars to become a reality.

It is worth noting that there are other related models, such as 20-minute cities (Da Silva et al., 2020), 45-minute regions, or Transit Oriented Development[24] which are better suited for less dense contexts, suburban areas, or even rural settings.

The 15mC and other similar models also try to bring the human scale to urban planning, where people are central in determining the use, quality and design of public spaces. Public spaces, streets, and roads are not just for the movement of people and goods but are also places to stay, socialise, and experience the city. Therefore, quality, safety, and diversity of functions are essential. As a consequence, trips tend to be shorter and, therefore, more conducive to active travel modes such as walking, cycling, public transport,

[23] Inforegio - New Leipzig Charter- The transformative power of cities for the common good (europa.eu)
[24] TOD is RUR https://www.todisrur.eu/

kick- or e-scooting, and even skateboarding. This can trigger a virtuous cycle to reduce negative externalities such as noise, air pollution, low liveability, road crashes, or social isolation.

Time-based urban planning concepts should be the cornerstone of future urban mobility planning. Promoting mixed uses and building density while fostering active modes and improving access to PT is a precondition for cities to reach sustainability goals and climate neutrality. Nonetheless, it is necessary to fine-tune and further develop time-based planning models for new developments as well as reflect on how they can be deployed and/or adapted to existing urban areas to boost their benefits.

Urban planning models based on proximity and time present an opportunity to tackle dissatisfaction or widespread discontent in areas where development has stalled and economic activity is declining. These areas are frequently disregarded as peripheries with inadequate connectivity and limited service availability, resulting in low levels of liveability that can detrimentally impact individuals, families, and whole communities. Therefore, urban planning models such as 15mC not only focus on spatial aspects but also aim to improve the sense of community and social cohesion through proximity, spatial, and social considerations. Diversity has a broader meaning and refers not only to mixed uses but also to inclusive and varied communities.

It is also worth considering how new mobility modes can fit these urban planning concepts, where active modes are prioritised. New technologies and mobility services should be leveraged as an opportunity to boost the uptake of time-based planning in more complex areas. The same can be said for the transport of goods, which are not considered in detail in these models and nonetheless play a significant role in people's lives.

As part of the UMWG discussion paper on Urban Mobility Towards the 15-minute city (2023)[25], several challenges regarding spatial planning and urban mobility were identified as in need of further research:

- **Intermodal solutions**. Time-based planning concepts such as the 15mC state that one should be able to access daily needs within 15 minutes of walking or cycle riding. However, in many large cities, this seems unattainable, particularly when it comes to accessing the workplace. Thus, it is also linked to the problem of affordability, resulting in many people not being able to access housing near their workplace for economic reasons. Therefore, the role of PT and NMS, among other solutions, must be researched further. In these solutions, digitalisation plays a pivotal role, with digital twins as part of the planning processes and mobility management, alongside integrated ticketing and seamless transfers. Considering space is a limited resource, it is important to assess the impact of different modes, as changes in one mode may affect others competing for the same space. The reallocation of space should be well-coordinated. Additionally, more attractive PT or NMS options may reduce the appeal of active modes, which could affect the model's core ideas. However, PT/NMS hubs can create more value by offering new services and by providing welcoming and attractive spaces if they are well-designed.
- **Reducing freight distribution's impact.** It is also worth analysing how last-mile delivery fits into the model. When goods move instead of people, these models do not seem to have a clearly aligned path forward. However, if freight and logistics are correctly integrated into the urban and mobility ecosystems, they can contribute to the improvement of street space use and safety, as

[25] ERTRAC-15minCity-paper_final-draft.pdf

well as reduce unnecessary trips and traffic. Last-mile delivery services based on crowd-shipping and informal logistic solutions can significantly contribute to a better use of land.

- **Applying consolidated urban policies to peri-urban areas.** For these models to be achievable, a certain level of density, diversity (people and land use alike), proximity, and digitalisation are needed. However, this is not the reality of most European urban peripheries, where density is usually lower, with strong zoning, large distances, and little real-time information available. How the model can adapt to these settings, be it through other versions already mentioned (45-minute regions) or other solutions, such as Transit Oriented Development, is still to be further studied. The link between urban, peri-urban, and rural areas also needs to be examined here, with attention to capacity-building, social inclusion, landscape specificity, and possible transit-oriented development strategies. It is also relevant to consider the importance of having a metropolitan scope for mobility that goes beyond the normal city/commuter zone scope and how such planning models can affect this.

In addition, some issues are closely linked to spatial design, such as the coexistence of modes and space for active modes infrastructure. At the same time, reducing the need for cars can give time and space back to people for other activities instead of mobility, allowing for a re-significance of the purpose of the public space. This can appropriately support the efforts and measures for climate neutrality in urban mobility and environments.

2.3 A fair twin transition

Shaping the Future of Urban Mobility in Europe is also driven by the policy context of the Twin Transition at the intersection of the "green" and "digital" transition, alongside the urgency to ensure these are also "just transitions". This calls for urban mobility projects, actions, and governance to centrally integrate considerations around sustainability, social justice, and digital society[26] [27].

The increase in fossil fuels' prices can disproportionally impact vulnerable households, microenterprises, and transport users who spend a larger portion of their income on energy and transport. In some regions, these groups may lack access to alternative, affordable mobility solutions and may not have the financial means to invest in reducing fossil fuel consumption. Transport poverty could become an even more pressing issue and result in diminished access to essential socio-economic activities and services such as employment, education, or healthcare, particularly for vulnerable individuals and households. Transport poverty is usually caused by one or a combination of factors such as low income, high fuel expenditures, or a lack of affordable or accessible private or public transport.

The expression "Fair Transition" considers how to make the move towards low-carbon societies fair and equitable for all communities and individuals. This concerns the city-level, the European perspective, and the global view – as they are all connected. Who benefits, and who is at risk of being left behind if the transition is not managed well? And how can the acceptability and proper democratic processes for the

[26] The twin green & digital transition: How sustainable digital technologies could enable a carbon-neutral EU by 2050 - European Commission (europa.eu)
[27] Council Recommendation of 16 June 2022 on ensuring a fair transition towards climate neutrality 2022/C 243/04

necessary changes be ensured? This is considered both in terms of people using urban mobility and in terms of employment related to mobility (e.g. car manufacturing, professional drivers).

The pressure on society and industry to speed up and scale up the transition to sustainable urban mobility will grow further. The chances of overlooking social justice implications, therefore, also become higher and pose significant risks to the required scale and speed of change across society and industry that is needed. Fair twin transition frameworks should be established to identify the negative social externalities of measures and solutions that generally improve urban mobility. These frameworks will support steady uptake and implementation, maximising benefits and positive outcomes for all.

Some manufacturing capabilities and their respective jobs might no longer be in demand. This shift in demand requires skills in other areas, potentially leading to job losses and associated negative social and justice implications. However, setting policies and frameworks that could lead to industry transformation or ensuring accessible professional training to meet the demands of new industries and businesses (e.g., the cycling industry) are crucial steps in mitigating these negative social implications. There are also unintended justice implications in terms of transport poverty for those who cannot afford transportation but need it for their income, such as small businesses and service providers in cities. Hence, the mobility patterns and needs of small businesses and service providers should be considered within urban mobility systems.

The prioritisation and promotion of active transportation modes should also be addressed with a critical and inclusive perspective. This involves examining and understanding which groups in society are more or less likely to have access to the benefits various modes offer and finding systematic ways to ensure that these benefits can be accessed by a diverse range of people. Thus, ensuring that the uptake of active modes is fair and just.

The focus on urban mobility means the concept of “mobility justice” is vital to consider alongside transition justice. Mobility justice examines how the mobility (and immobility) of people, things and information is shaped and governed unequally and inequitably. It is essential to consider who has access to urban mobility (or not), but also how risks and responsibilities are distributed (both locally and globally), how well-being and the ability to move around are impacted, which parts of the population get the attention they deserve, and which are vulnerable. It is also central to consider who is included in processes around deciding and designing urban mobility and how. The transition to a system built on sustainable mobility also has great potential for health and socio-economic co-benefits – including increased safety, a higher quality of life in cities, climate change adaptation, etc. Mobility transition policies should seek to maximise and promote such co-benefits, using systems and justice perspectives on the mobility transition.

Cities, regions, research and the private sector need to be attentive so that by solving one mobility justice problem, no new ones are created. New systems, services, measures and solutions need to ensure that the accessibility and inclusion gap does not increase for user groups that have been historically vulnerable to exclusion from transport systems. At the same time, mitigations are in place to tackle the risk of excluding user groups that previously had sufficient access to the transport system.

As mobility becomes increasingly intertwined with data and the importance of AI grows, data justice concerns are also crucial for transitioning to sustainable urban mobility, for example, whose mobility data is collected, who collects it, and how it is used. Being mobile increasingly involves the production, storage, processing, and sharing of data (consciously or not), from car sensor data for diagnostics, insurance apps

for driving, ticketing apps for PT, urban micromobility shared schemes, Google maps and other route planning apps, fitness and well-being apps, Internet of Things sensors, AI in migration "management", air pollution data, and more. This means that future urban mobility needs to consider whose mobility is included or excluded in the collection and sharing of data, in what ways, as well as whether certain mobilities are enabled and restricted through data, and how the access and ownership to mobility and data are changing. These data and mobility justice concerns also have implications for the governance of green/digital transitions around urban mobility.

Data governance plays a central role with regard to a just and digital transition towards more sustainable urban mobility. A wide range of actors come together in governance, including industry, the public sector, third sectors, and citizens, with different roles and power relations in terms of engaging, deciding and accountability. Data governance can be understood as multi-stakeholder processes around managing data assets. The platform economy favours data governance models that mainly benefit large corporations. The interests of the public sector, industry, and citizens need to be more balanced around mobility data governance. It is therefore important to explore how small and medium enterprises (SMEs), as well as public sector and civil society organisations, can be more centrally involved in mobility data governance to ensure sustainability and social justice goals are met alongside economic ones. This includes considering stakeholders' roles and relationships, how societal and economic values are articulated in goals/optimisations, and what the principles of governance are. Mobility projects and initiatives can thereby contribute to the redistribution of value that is produced through data, generating greater benefits from European data and greater control over it.

What is not fully understood yet is the governance implications of having data (and increasingly AI) centrally involved in urban sustainable mobility. For example, are the AI-driven shared mobility/MaaS platform models optimised for sustainability, social justice, or business goals? Does AI become an actor in urban mobility governance, and if so, what are the implications? Do mobility and transport professionals and policymakers have relevant data and AI skills? Do they know which questions need to be asked to ensure that the algorithms used do not discriminate against groups that are already commonly disadvantaged?

Hybrid governance for sustainable mobility requires close collaboration between city policymakers and industry players while also acknowledging AI algorithms as important non-human agents. It is central to work out how this should look in practice. Relevant context of the data governance of urban mobility includes the European General Data Protection Regulation (GDPR), and Acts on Digital Services[28], Digital Markets[29], Data[30], and AI[31].

Moreover, when NMS and other technological solutions are being planned and implemented to support the sustainability of mobility systems, it is important to consider the risk of digital exclusion of some user groups (e.g. elderly, people with a low income, digital illiterates) and the need to strike a balance between digital and non-digital solutions and services for end-users. This will help ensure that no one is left behind.

Overall, social justice must become more central in discussions and actions towards transitioning to more sustainable urban mobility. On the one hand, concerns from those with legitimate fears about being left

[28] The Digital Services Act package | Shaping Europe's digital future (europa.eu)
[29] Digital Markets Act (europa.eu)
[30] Data Act | Shaping Europe's digital future (europa.eu)
[31] AI Act | Shaping Europe's digital future (europa.eu)

behind must be addressed with concrete solutions. On the other hand, some people may experience a potential loss of privilege as discrimination. Clear and consistent communication about a shared positive vision of a future with fewer cars and more sustainable and people-friendly mobility will be needed to counter both types of concerns. Concepts and theories must be better operationalised for use by policy and industry, for example, towards inclusion in tools, standards, and standard methods. City, EU and global perspectives need to be linked. Emerging work with regard to gender, age, and socioeconomic needs to become part of the mobility mainstream. While inclusion and accessibility are vital, social justice is a topic that requires consideration beyond these aspects to ensure the transitions are just.

Therefore, it is crucial for a wide range of mobility stakeholders to systematically develop knowledge and skills around the idea of a just transition. It is also important to develop and apply social justice impact assessments for urban mobility that consider transition, mobility, accessibility, and data justice elements.

The EC recognises the societal strains that the twin transition will bring: the digital and climate transition will have an economic and social impact that is difficult to assess ex-ante. Achieving the increased climate ambition will require substantial public and private resources. Accordingly, within Fit for 55, the social climate fund is dedicated to supporting households, micro-enterprises, and transport users in vulnerable situations. It aims to address energy poverty and enhance the availability of zero—and low-emission transportation and mobility in the EU[32]. Moreover, the EU Just Transition Mechanism aims to protect vulnerable groups, industries, and regions during the transition to a low-carbon economy as per the EU Green Deal. It will facilitate employment opportunities, re-skilling, and investments in energy efficiency and clean energy. Additionally, it will support the transition of carbon-intensive industries, create new jobs in the green economy, invest in renewable energy and sustainable transport, and mobilise around €55 billion over the period 2021-2027[33].

Within the outlook of urban mobility, it is relevant to consider the increased integration between digital society, Information and Communication Technology (ICT), data, AI activities, and transport and mobility activities, ensuring future urban mobilities are more sustainable while at the same time considering social justice. Moreover, ensuring that regulatory frameworks for AI and data in urban mobility centrally consider sustainability, and vice versa, is a way to strengthen the systematic integration of the twin transition so it can better realise its potential. It is crucial to develop urban mobility stakeholders' skills, knowledge, and tools that are relevant for a just and digital transition.

2.4 Improving road safety policies

Road safety continues to be a source of concern in urban mobility. From EC figures[34] [35] on Road Safety in the EU, it shows that **around 20,400 people were killed in road crashes in 2023**, a small 1% decrease from 2022. This represents, however, 2,360 fewer fatalities (-10%) compared with the pre-pandemic year 2019. EU-wide, more than 2,000 cyclists were killed in 2022. Remarkable is that within urban areas,

[32] Fit for 55 a fund to support the most affected citizens and businesses
[33] The Just Transition Mechanism - European Commission (europa.eu)
[34] https://transport.ec.europa.eu/background/road-safety-statistics-2023_en
[35] https://www.nrso.ntua.gr/european-commission-road-safety-in-the-eu-march-2024/

vulnerable road users (pedestrians, cyclists, and users of powered two-wheelers) represent almost 70% of total fatalities.

Road crashes cause approximately 1.3 million deaths annually, surpassing fatalities from HIV/AIDS or tuberculosis, and are the leading cause of death for individuals aged 5-29 years. The UN Sustainable Development Goals highlight road safety, aiming to halve global road traffic deaths and injuries by 2020 (SDG 3.6) and provide safe, affordable, and sustainable transport systems by 2030 (SDG 11.2).

In the EU, road safety improved significantly from 2000 to 2010, with a 45% reduction in fatalities. However, progress has stagnated from 2013 to 2019, and fatalities rebounded slightly in 2021 post-COVID-19 lockdowns. In 2022, the EU reported 20,678 road fatalities, a 4% increase from 2021. Despite improvements, the EU is not on track to meet its target of zero fatalities by 2050. The Vision Zero policy and the Safe System Approach are crucial for future road safety policies, but current trends indicate substantial additional efforts are needed. Effective road safety measures face funding challenges, despite rising socio-economic costs of road fatalities and severe injuries. Enhanced public funding is required for road safety research and innovation, focusing on the Safe System Approach and technologies supporting sustainable road transport.

Connected, Cooperative, and Automated Mobility (CCAM) is expected to reduce collisions significantly, but its initial impact will be limited to domains like highways and confined areas. Rural roads, where more than 50% of road fatalities occur, may not benefit from highly automated driving by 2050. Non-technological research is needed to understand crash circumstances, human factors, and the interaction between users, vehicles, and infrastructure.

The Safe System Approach, which focuses on strengthening all layers of road safety to ensure redundancy, is widely supported. The EU Road Safety Policy Framework 2021-2030 calls for increased funding for these strategies, but current research and innovation funding is inadequate. The Vision Zero mindset asserts that no loss of life is acceptable, necessitating a significant upgrade in funding and attention to road safety research. Effective road safety measures will reduce human suffering, save thousands of lives, reduce the burden on healthcare systems, and cut socio-economic costs by billions of euros.

For Road Safety priorities, we refer to the ERTRAC's Safety Working Group's excellent Safe Road Transport Research Priorities for 2025 Safer and More Sustainable Mobility for All. Specifically, the two priorities defined in the document: "Safety of Bicyclists and Users of other Micro-mobility Devices" and "Safety of Users of Small Electric Vehicles" are of specific relevance for the urban mobility system.

3 RESEARCH AND INNOVATION METHODOLOGIES

The position of Urban Mobility in EU research is changing. More initiatives have UM in focus and take R&I innovation forward. In general, Urban Mobility research and innovation is often part of cross-sectoral research (embedded in urban transition research), becomes more multi-disciplinary (with a strong focus on Social Sciences and Humanities), and strongly focuses on deployment, scaled implementation, and market-take-up. This chapter describes the changing R&I landscape for UM, the way cities can function as living labs (3.1), how the pathway to implementation can work (3.2), and how to measure the impact and the long-term assessment of local R&I efforts (3.3). All of this can be set in an international dimension, outlined later under the section “Urban Mobility in International Cooperation” (5.16).

Since the previous ERTRAC-ERRAC-ALICE Urban Mobility Roadmap, a lot has changed in the European Innovation ecosystem about Urban Mobility R&I. New or strengthened institutionalised programmes have appeared that enable a new approach to innovation in this field. The roadmap can inform and bring added value to these communities. Each of these structures mentioned initiates funded R&I activities, including activities linked to urban mobility:

- **CCAM partnership**: Co-programmed with the European Commission in the Horizon Europe Framework to create a more user-centred and inclusive mobility system, increasing road safety while reducing congestion and environmental footprint.
- **2Zero partnership:** Co-programmed partnership to accelerate the transition to a European carbon-neutral road transport system by 2050[36].
- **Driving Urban Transitions:** Sustainable future for cities – (initiated by the JPI Urban Europe) through research and innovation, it enables local authorities and municipalities, businesses, and citizens to translate global strategies into local action.
- **EU Mission: Climate-Neutral and Smart Cities:** The “Mission” aims to create 100 climate-neutral and smart cities by 2030, turning these cities into living labs that inspire all other cities. The Missions have their own Work Programme in Horizon Europe.
- **New European Bauhaus (NEB):** A creative and interdisciplinary initiative that connects the EGD to our living spaces and experiences. The NEB has its own space in the Work Programme in Horizon Europe.
- **EIT:** Different Knowledge and Innovation Communities (KICs) are active in the field of urban mobility (EIT Urban Mobility, InnoEnergy, Climate KIC). A KIC is a highly integrated, creative, and excellence-driven partnership that brings together the fields of education, technology, research, business, and entrepreneurship to produce new innovations and innovation models that inspire others to emulate them.
- **INTERREG:** Interreg Europe is an interregional cooperation programme co-funded by the European Union. The European Union strives to reduce disparities in the levels of development, growth and quality of life in and across Europe’s regions. Innovation is key.
- **LIFE Programme:** The LIFE Programme is the EU’s funding instrument for the environment and climate action.

[36] 2ZERO Partnership Strategic Research and Innovation Agenda 2021-2027

- **CIVITAS initiative:** Groups the Horizon Europe project with a specific Urban Mobility focus.

3.1 Cities and districts as living labs

Urban experimentation and open innovation ecosystems, such as living labs, test beds, and demonstrators, often suffer from a lack of standardised terminology and multiple definitions. This situation has put the term “living labs” at risk of becoming a mere buzzword. However, using living labs has become a well-known concept, representing versatile entities that can be considered ecosystems, environments, or innovative methodological approaches. What unites them is their capacity to drive research and innovation projects aimed at addressing critical societal challenges while keeping people at the forefront of the innovation process.

A common living labs approach that fosters open innovation and tests a series of innovation options in real communities as a standard for urban mobility research and as a basis for further knowledge transfer between urban mobility stakeholders is crucial for the future of sustainable mobility. This includes the access to relevant data from living labs as a key condition for maximising the living lab learning and innovation potential.

The European Network of Living Labs (ENoLL) defines[37] living labs as real-life innovation ecosystems that use iterative feedback processes to create sustainable impact. Living labs focus on co-creation, rapid prototyping, testing, and scaling up innovations and businesses, delivering joint value to all involved stakeholders. They act as intermediaries between citizens, research organisations, companies, and government agencies. Although living labs come in various forms, they share common characteristics while being implemented in diverse ways.

While living labs offer numerous benefits for innovation and urban development, such as balancing various scales of cities, services, personnel resources, and investments of time, they also come with several challenges. The challenges include, among other things, ensuring a diverse and representative group of users, privacy and safety concerns, managing scale, time-consuming processes, etc. (Compagnucci, et al. 2021).

It is important to recognise that the living lab approach should be considered as a tool for inclusive co-design processes. Living labs should not be driven by a specific technology or innovation but rather by the effort to address key objectives.

In the ERA4CS project EVOKED, a review of living labs was carried out, resulting in six living lab principles summarised as such: continuity, openness, realism, influence, value, and sustainability[38]. For EIT Urban Mobility, five key elements define living labs: real-life environment, triple/quadruple helix stakeholder participation, co-creation, active end-user involvement, and a multi-method approach[39]. A living lab should also be time-bound and can be part of citizen science to engage with people for innovation and data

[37] https://enoll.org/about-us/what-are-living-labs/
[38] EVOKED project D1.1 Living Lab Co-Design Requirements Guiding Paper
[39] EIT Urban Mobility living labs - EIT Urban Mobility

collection[40] (Veeckman and Temmerman 2021). However, implementing these elements can vary widely, adapting to specific contexts.

Many of the open innovation ecosystems of this nature are either owned or managed by public authorities. Leading cities often take the initiative themselves or delegate it to dedicated entities. For instance, Helsinki's Forum Virium, Stockholm's KTH, Greater Copenhagen's Gate 21, Amsterdam's AMS Institute, and Barcelona's Bit Habitat are notable examples.

The most successful living lab initiatives go beyond fixed-location testing facilities. They offer a range of complementary services that enhance their impact. These services include facilitating engagement with active user groups, providing access to funding, fostering matchmaking among stakeholders, offering skill development opportunities, and supporting project development.

Living labs play a vital role in research, development, and collaboration in a world driven by innovation. They contribute to making cities and districts better places to live by actively involving people in the innovation process.

In order to enable the living lab projects to contribute on a broader scale to the necessary EU and local targets, successful living labs should set a vision and targets through participatory foresight activities and receive support via access to investors through both the EU and new forms of funding sources such as sustainable and social impact funds. Moreover, living labs would benefit from having a dialogue with each other and exchanging best practices. Establishing close cooperation with existing living labs would allow cities, practitioners, experts, business developers and entrepreneurs to transfer and scale up successful innovations.

Collaboration with end users and/or citizen empowerment is crucial since, for example, offering responsibility and the final decision to end users and citizen empowerment can help living labs improve the adoption of innovation and solutions. This could be done by creating and/or facilitating end user/citizen engagement platforms available to all urban mobility living labs. Another critical aspect for established living labs is the retention rate of companies which are customers of the living lab, as well as maintaining their overall engagement in the living lab processes. Living labs must remain interesting to participating stakeholders, stay on top of ongoing policy and regulatory and innovative developments, and understand the local mobility market and stakeholders.

Moreover, for living labs to be enablers for transformative change towards more sustainable mobility in cities, including contributing to climate mitigation and adaptation, they could adopt wider transdisciplinary contexts (technology, natural and social sciences, humanities). For example, living labs could work as hubs to create engagement between scientists, artists, and the public. Integrating various people and using art to convey scientific knowledge emotionally for a deeper understanding could bring new insights and perspectives to the path towards the decarbonisation of mobility. Additionally, living labs could be a means of realising and evaluating future deployment scenarios and delivering more efficient and effective outcomes when considering disaster preparedness and resilience strategies.

Creating a pan-European knowledge transfer platform would help reduce the gap between living labs. Currently, there are a wide variety of living labs in the European Union, with differing maturity and readiness levels. Additional factors, such as engagement with the local innovation ecosystem and

[40] EVOKED project D1.1 Living Lab Co-Design Requirements Guiding Paper

infrastructure/services offered, should be considered when assessing these readiness levels. Moreover, fostering a culture of experimentation in European cities and regions would allow them to reduce risks associated with the further uptake of new mobility services and frameworks. Finally, European living lab initiatives require additional local and EU support in funding and financial sustainability, stakeholder engagement, and managing outputs and results. Economic sustainability mechanisms should be further developed for European living labs. It is important that both private investors and cities invest in living labs.

3.2 Preparing implementation: Transferability, upscaling and capacity building

EU-funded R&I projects in the transport sector have played an essential role in advancing innovations, accelerating digitalisation, providing more inclusive services, reducing emissions and pollution, improving efficiency, and strengthening competitiveness. Such R&I projects have also created opportunities for cooperation among various stakeholders, enabled new business models, created new enterprises and developed decision support tools, practitioner guidelines and policy recommendations. Dissemination and exploitation are an important part of R&I projects to ensure projects' uptake. Although project proposals have already included dissemination and exploitation plans, it has been noted that not all project results have been exploited, and expected societal impacts may not be optimally delivered.

To address this shortcoming in exploitation, the European Commission (EC) has requested that all Horizon 2020 and Horizon Europe projects should plan their dissemination and exploitation activities beyond the EU funding deadline. After the end of the Horizon 2020 programme (2014 – 2020), the Horizon Results Platform[41] and Horizon Results Boosters[42] dedicated to the exploitation of Horizon 2020 projects have been set up. In addition, various support schemes are available for follow-up steps, e.g., national programmes, InnovFin: EU finance for innovators, Regional Funds, Enterprise Europe Network (EEN), and European Intellectual Property (IP) Helpdesk. A Task Force on Accelerating Innovation Uptake for Sustainable Transport[43] was launched in 2021 jointly with several CSA projects funded by H2020. The Task Force also published a "Call for Action" to support the uptake of Horizon 2020 and Horizon Europe projects' results in the transport sector.

During the projects' lifetimes, it is crucial to assess and evaluate the possible challenges that project partners will face in delivering outcomes and expected impacts beyond the project funding period. This should be an exercise done by project partners and by the EC. Project participants should recognise the importance of implementation, transferability, and upscaling rather than focusing solely on completing project tasks. Besides having ambitions to continue their work beyond EU funding, project partners should benefit from continuous EC support on how to do so, with possible training on transferring projects' outcomes to successful businesses, new products, new policy measures, etc. That might be achieved by collecting and showcasing the successful uptake of past EU-funded R&I projects. Having a stock of past success stories is relevant to developing guidelines based on them to raise awareness and help project

[41] Horizon Results Platform | Making Result Matter
[42] Horizon Results Booster
[43] The Task Force was launched in December 2021, https://www.etp-logistics.eu/launch-of-the-task-force/

beneficiaries design proposals, implement projects and further exploit project results to achieve real impact, create successful businesses, and achieve breakthrough innovation.

Exploring collaborations and moving away from standalone projects is an essential part of boosting transferability, upscaling, and capacity building. Project clusters that can be formed either as part of the Horizon Results Booster, CIVITAS, or simply by related topics are efficient ways for projects to find synergies and learnings, combining efforts in exploitation actions. Within clusters, projects and partners can reinforce cooperation and allow the gaps and limitations that individual projects might have to be addressed and surpassed. Thus, emphasising and ensuring that such activities are part of proposals is essential so that project partners can dedicate enough time and personnel. Moreover, systematically making such cluster activities part of proposals will support creating a culture of collaboration that will support transferability and upscaling. New calls and funding opportunities should also build upon such clusters and encourage continuation based on results and identified exploitation opportunities, either commercial or policy focused.

Numerous projects develop useful toolkits, decision support tools, practitioner guidelines, and policy recommendations that are aimed at regional and local authorities, such as the ones part of the CIVITAS Urban Mobility Inventory[44] that is a common repository of resources for urban mobility. It is essential to assess how these efforts and results are utilised and implemented after the projects' conclusion to continue mainstreaming these outputs into local policies or scaling the solutions already tested on a limited scale. Factors such as the organisational and institutional capacities, supportive European and national policies, financing, technical skills, and collaborations need to be considered to understand whether regional and local levels can absorb these outputs. Dedicated funding of CSAs, which would bring these tools together and work on capacity-building, transferability and scaling with a larger group of cities and regions, would be beneficial and increase the legacy and (non-commercial) exploitation/deployment of previous project outcomes.

R&I topics should also be developed together with industry experts who will use project outcomes to address the challenges the European industry faces and strengthen its competitiveness. Attention should also be given to including business and marketing experts in the project consortium to support market uptake, allowing for exploitation and business plans to be developed within the projects' lifetime and accomplished later.

The further development and application of transferability methodologies, cost-benefit analysis and impact assessment should be envisaged to mainstream urban transport innovations in cities. This can also be used in an international cooperation context.

The primary focus of transferability, upscaling, and capacity building actions must revolve around fostering an innovation culture and establishing the necessary contextual conditions. This includes:

- Political backing and support are crucial drivers since political power often influences other pertinent frameworks that help break barriers and facilitate deployment.
- Public acceptance of innovation is a preeminent factor, intrinsically linked to political support.
- Access to financial support is imperative for driving successful deployment and usually stems from politically initiated development funds or direct political initiatives.

[44] https://civitas.eu/tool-inventory

- Coherence in legal frameworks across all relevant levels is essential for certain innovation measures and acts as a catalyst for the wider adoption and deployment of innovation.

3.3 Measuring impact, long-term assessment of local R&I efforts

Understanding the impact of measures to address greenhouse gas emissions, safety, and other road transport challenges is critical to identifying which measures are most effective and what else needs to be addressed. Growing digitalisation, data collection, analysis, and impact assessment at local level, facilitated by new technologies, should be aligned with wider sectoral and EU-level practices and priorities, and vice versa, in order to use resources efficiently, minimise the burden on cities, and enable transparent assessment and evidence-based decision-making.

One approach to build on is the CIVITAS Process and Impact Evaluation Framework, which can be enriched with other approaches. Several transport partnerships, such as CCAM and 2ZERO, have developed impact assessments of mobility initiatives that could be applied to urban mobility research. Whichever approach is taken, it is important to balance the needs and capacities of cities, for example, by allowing them to select the targets and indicators that work for them, with the benefits achieved through enabling an overview of impacts on an EU level. This involves considering the local pace, in terms of the capacity for implementation and evaluation, versus the EU pace.

A common data collection system should be developed among European cities to ensure a streamlined application of the sustainable urban mobility indicators (SUMI) to be reported on by urban nodes according to the TEN-T Regulation. Moreover, it is important to establish lasting support structures for the gathering, analysis, and documentation of data on sustainable mobility using the SUMI indicator set (or other indicators).

It is also important to consider pragmatic solutions to avoid penalising cities that already collect large amounts of data which do not align with the current or future impact measurement standards, as well as smaller cities and others that struggle to supply reliable data. Building capacity and developing skills to bridge the digital divide between the public and private sectors will be instrumental in this respect. For instance, assessing the concrete impacts of the deployment of NMS can support improved and more informed decision-making, enhance the enforcement of regulations and help to prioritise investment.

There is a need to support the exchange and cooperation with mobility stakeholders to collect required data, define data-sharing protocols and use cases, and build capacity in public administrations to manage this cooperation and exploit the available data to support decision-making and policy design.

4 RESEARCH NEEDS, PRIORITIES AND MILESTONES – FRAMEWORKS AND ENABLERS

4.1 Governance and regulations

In recent years, various innovative services, supported by brilliant business models and ground-breaking technology innovations, have achieved excellent market penetration and brought improvements to multiple aspects of people's lives, particularly in urban areas. Some of these solutions, such as home delivery services, e-commerce, and shared mobility, have significant impacts on urban mobility and, in some cases, negative implications in terms of emissions, road safety, congestion, occupation of public spaces, and coexistence with other transport systems.

These innovations have had such a sudden market penetration that local authorities did not have the time to effectively address them with monitoring, planning, regulatory, and enforcement tools capable of counteracting negative impacts while maximising opportunities. If this does not happen before a massive adoption by consumers, it can become difficult, and sometimes unpopular, to implement any form of limitation or improvement. Cities and local authorities end up with reactive approaches rather than proactively planning for these new innovative services and mobilities.

Governance and regulations should also encompass a broader variety of disciplines and research approaches involving social sciences and humanities alongside sciences, technology, engineering and mathematics (STEM) to assess not only the levels of technology readiness but also societal readiness levels. In this sense, not only institutional silos and political-administrative boundaries need to be overcome, but also the fragmentation between knowledge fields. Collaboration across diverse disciplines at various stages of policymaking is essential for developing systemic approaches for transition pathways. This entails fostering anticipatory thinking to anticipate and address future challenges while ensuring that decision-making processes are participatory, transparent, and representative. This is essential for enhancing the resilience and responsiveness of urban mobility systems.

R&I activities should include:

- Exploration of case studies and examples of interdisciplinary collaboration in policymaking and urban mobility systems, reviewing academic literature on technology readiness, societal readiness, and systemic approaches for transition pathways;
- Analyses of the challenges and benefits of interdisciplinary collaboration in decision-making processes with the compilation of data and statistics related to urban mobility systems and societal impacts of policy decisions;
- Evaluation of the role of anticipatory thinking, transparency, participatory decision-making, and data justice in governance and regulations.

Results are expected to contribute to the following outcomes:

- A better understanding of the effects of land-use legislation on optimal space distribution

- Governance models for urban logistics innovation and financial sustainability;
- Governance models that effectively promote collaborative and integrated mobility planning, encompassing physical proximity and digital connectivity;
- Engaging stakeholders and delineating data-sharing governance to address their points of view and concerns, as well as data justice;
- Appropriate governance and collaborative business models for data sharing and data-driven services that are common, mutually acceptable, and useful to stakeholders;
- Improving cooperative governance models for sharing assets and other facilities among public authorities, technology and mobility providers, urban logistics service providers, and real estate.

Governance and regulations are considered a priority (projects concluded by 2030) that requires a full call topic development.

4.2 SUMPs

Sustainable Urban Mobility Plans (SUMPs) play a vital role in the urban mobility policy of Europe. They can greatly enhance the quality of life of city dwellers by tackling key issues such as congestion, air and noise pollution, climate change, road safety, health, inclusion, logistics, and parking. In addition to that, SUMPs create a platform for innovation and the assimilation of new mobility services[45].

SUMPs should play a key strategic role in developing more integrated, sustainable, socially inclusive, resilient, and flexible mobility solutions, duly addressing the needs of people and businesses in cities. Moreover, they should have a strategic role in addressing broader sustainability goals in cities and working together with other policies and instruments to improve overall quality of life. They work as long-term plans that tackle short-term objectives by developing sets of actions guided by broader visions. Thus, SUMPs must be coordinated and aligned with different regional and mobility plans that compose the visions and outlooks of cities for a climate-neutral future.

SUMPs should be regarded beyond their legal obligations under the new TEN-T regulations on urban nodes, as they can provide a solid strategic framework for all cities, regardless of their size, to continuously improve mobility. Evaluating current SUMPs will support the development of next-generation SUMPs, allowing for constant progress. Additionally, SUMPs need to cover the entire functional urban area (FUA)[46] and should consider intermodal solutions, promoting active modes and green solutions, and encompassing a multitude of integrated potential mobility services (based on digital tools).

The design and deployment of effective SUMPs require the use of strongly participatory approaches and the set-up of clear, consensual evaluation and monitoring mechanisms. Raising public awareness of the benefits and importance of SUMPs outcomes is essential for the success of the planning and implementation process. Therefore, designing and implementing engagement activities that are diverse and accessible for various stages of SUMP development and implementation and allow for greater representativeness and inclusion is essential to address equity aspects, including gender and intergenerational considerations. Inclusive approaches ensures that diverse perspectives are considered

[45] https://transport.ec.europa.eu/transport-themes/urban-transport/sustainable-urban-mobility-planning-and-monitoring_en
[46] Functional urban area consists of a city and its commuting zone

in the planning process, leading to more equitable and sustainable urban mobility solutions that cater to the needs of all residents, regardless of age, gender, or socio-economic status.

Large urban areas are often characterised by significant socio-spatial inequalities, which are strongly correlated with transport poverty. Recognising the importance of functional urban areas and understanding the mobility dynamics of a territory beyond political-administrative borders is crucial. Planning efforts should transcend traditional boundaries to address the interconnectedness of urban areas, fostering collaboration and coordination among neighbouring municipalities to develop integrated and cohesive mobility strategies that reflect the realities of the entire functional urban area. Collaborative governance models can be strategic for this, as mentioned above.

In accordance with recommendations (EU) 2023/50550 from 8 March 2023, the European Commission urges every Member State to establish a SUMP national support programme. This initiative is designed to bolster and empower cities, enhance governance, foster nationwide coordination and cooperation among regions, cities and towns and between urban and rural areas, promote integrated planning and facilitate the adoption of SUMPs.

R&I activities should create opportunities for these national support programmes to materialise and address the actual needs of local authorities and populations, either in terms of professional capacity or actions. Moreover, the national support programmes should examine how they can support neighbouring and interdependent municipalities to improve their collaboration and create common vision that can support individual ones

R&I should also develop innovative, interdisciplinary, multi-method, easy-to-use procedures to design, deploy and monitor new SUMPs or refine existing ones.

These procedures should be generic enough, based on a set of simple, comprehensive and sound principles and guidelines, but easily scalable and customisable.

For each city or metropolitan area, these research results and approaches should be used according to their specific characteristics, following a strategy that considers agreed goals, available resources, and the needs and expectations of the multiple involved stakeholders.

Tools need to be developed to simulate the relationships between mobility plans and other sectors for the mobility of both people and goods and to evaluate and compare planned and performed impacts at present and in the medium- and long term. The policy and governance dimensions should be viewed as a critical part of the research.

R&I activities should include:

- The development of “digital twins” of the main mobility processes involved in the geographical area under study, based on various forms of data and collected through multiple channels;
- The construction of a conceptual “framework” to support decision makers in analysing scenarios and measures, helping them to make choices in a multi-criteria perspective and to define implementation strategies;
- Exploring big data, modelling, and monitoring tools for better services and policymaking;
- The design and experimentation of new forms of democratic participation and people’s engagement, including fairness and social justice;

- The integration of other fields such as climate mitigation, climate change adaptation, energy, logistics, sustainable transition, inclusion etc.

Results are expected to contribute to the following outcomes:

- SUMPs should lead to better integrated, resilient, energy-efficient and equitable urban mobility systems, guaranteeing multimodality and ensuring integration with long-distance mobility systems.

SUMPs are a priority topic (projects concluded by 2030) that requires a full call topic development.

4.3 SULPs

According to the Organisation for Economic Co-operation and Development (OECD), urban freight is responsible for a quarter of all vehicles in cities, contributing to 40% of urban transport-generated CO2 emissions and 50% of air pollution in cities. European cities are working to achieve the ambitious goals towards a net-zero future, investing in sustainable, innovative solutions. However, urban logistics remains a complex challenge.

Urban logistics is a very fragmented industry, accounting for high-cost technologies and low-level collaboration among stakeholders reluctant to share data. At the same time, it represents a fundamental service for local communities and supports a substantial part of commercial activities contributing to local economic development. Over recent years, cities have expressed growing concerns about the impacts of urban logistics, encompassing traffic congestion, noise and air pollution, land use issues, and crashes.

By approving the EGD and the Sustainable and Smart Mobility Strategy (SSMS)[47], the European Union committed to achieving the objective of reducing emissions by 90% by 2050 (compared to 1990 levels) by supporting the development of smart, competitive, safe, accessible, and affordable transport systems. The SSMS, in particular, aims to enhance the sustainability of all modes of transport, outlining specific actions that foster health and sustainability in interurban and urban mobility and advancing the greening of freight transport.

One crucial approach to realising these objectives is implementing Sustainable Urban Logistics Plans (SULPs), recognised as a vital policy instrument. SULPs play a pivotal role in integrating the freight dimension into urban planning processes and accelerating the adoption of available zero-emission solutions within the freight sector. Nevertheless, it remains crucial to acknowledge the multifaceted factors influencing the choices made by logistics actors when opting for more sustainable practices, spanning considerations of operational efficiency, environmental impact, and economic viability.

The SULP approach is connected to a SUMP, which should include and enhance the city logistics aspects. SUMPs and SULPs are strategic interconnected plans dealing with the complexity of urban transport and logistics, which involve a variety of stakeholders while trying to achieve a balance between the industrial requirement for high efficiency and low-cost operations and societal needs for low CO2, high safety, and

[47] https://transport.ec.europa.eu/transport-themes/mobility-strategy_en

sustainability. However, the already mentioned EC Recommendation for Member States to have national SUMPs support programmes leaves out SULPs.

It is, therefore, challenging to achieve actors' collaboration and participation in the planning process and to conclude upon measures that can be successful and largely adopted in different urban contexts. SUMPs and SULPs advocate for fact-based decision making guided by a long-term vision for sustainable mobility and logistics. However, these approaches still start from a sectoral point of view and are not able to address the different local and FUAs strategic spatial planning mechanisms in a sufficiently integrated manner.

The separate planning processes of SUMPs and SULPs can result in fragmented decision-making, with different departments or agencies responsible for mobility and logistics, and this can hinder the adoption of holistic and sustainable solutions. Urban areas with separate mobility and logistics plans may struggle to meet environmental goals, such as reducing greenhouse gas emissions and improving air quality, as the lack of integration can impede progress in achieving these objectives. When SUMPs and SULPs are developed separately, there is often a lack of coordination and synergy between mobility and logistics strategies, resulting in inefficiencies, duplication of efforts, and missed opportunities for optimisation.

Inadequate coordination between mobility and logistics planning often leads to increased traffic congestion and air pollution (e.g., poorly planned delivery routes can contribute to traffic jams that also affect urban mobility and worsen air quality). Without integration, cities may invest in infrastructure and initiatives that do not consider the needs of passenger and freight transportation. This may lead to inefficient use of resources and missed opportunities to leverage shared infrastructure.

Last-mile delivery is a critical component of urban logistics, and the lack of integration of SUMPs and SULPs creates difficulties in optimising last-mile delivery, resulting in inefficient and polluting practices and increased costs for businesses and consumers. These costs can be exacerbated when logistics and mobility plans do not work together to streamline operations. In summary, the absence of coordination between SUMPs and SULPs can limit the potential for sustainability gains. When urban mobility planning focuses solely on passenger transport without considering how it can support sustainable goods movement, the overall environmental and economic benefits may be compromised, which causes a negative impact on the quality of life for urban residents, including congestion, noise, and air pollution, resulting from disjointed planning efforts. This can subsequently lead to health problems, reduced well-being, and decreased city liveability.

Thus, projects must identify specific needs related to freight demand, public space redesign, freight unloading practices, delivery models, data availability, coexistence with other transportation modes, define short- and medium-term plans interrelated with other sectors under the responsibility of local authorities, and implement appropriate measures to implement the necessary changes within the project schedules. These should foster collaboration, align objectives, and leverage data-driven insights to optimise urban mobility and logistics in an integrated manner, thereby creating more resilient and sustainable urban transportation systems that benefit residents and businesses while addressing environmental and congestion challenges. In this context, crowd-sourcing and strong citizen participation can be key for the design and successful implementation of new last-mile delivery solutions.

In addition, projects are expected to identify and provide clear guidance to cities and Member States regarding deficiencies in data collection and harmonisation methodologies and to propose new standards

to compare and evaluate results over the years and among cities. Such data should, where possible, be integrated with cross-domain data to ensure the analysis of interdependencies of all policy instruments.

A thorough evaluation, with a clear baseline definition in each city, should provide qualitative and quantitative information on the results of the local solutions implemented. The success of the proposed measures in attaining policy objectives, especially in the realms of urban logistics practices and addressing climate and pollution concerns, should be subjected to rigorous evaluation. Simultaneously, it is crucial to pinpoint any obstacles that might hinder widespread adoption and deployment. Comprehensive recommendations for overcoming these barriers should be developed to facilitate progress, ensuring a smoother path towards a more sustainable and efficient urban logistics system. This process should be accompanied by mechanisms for common lessons and learnings within and between projects funded under this topic and through the CIVITAS Initiative.

R&I activities should include:

- Innovative approaches, including stakeholder engagement strategies, user acceptance, cross-sectorial co-design, community engagement, and behaviour change;
- Technology scouting to identify appropriate tools supporting urban logistics measures;
- Data integration and analytics, including innovative methods for integrating mobility and logistics data to provide a comprehensive view of urban transportation and exploring data analytics and machine learning techniques to identify optimisation opportunities and improve decision-making;
- Green and sustainable mobility and logistics technologies, including 2Zero and CCAM solutions and exploring the use of renewable energy sources and energy-efficient technologies in logistics operations;
- Studies of the design and effectiveness of Urban Consolidation Centres (UCC) in reducing the number of delivery vehicles in urban areas, including innovative UCC models with shared logistics and mobility hubs;
- Exploration of platforms and applications that promote ridesharing, carpooling, and collaborative logistics among businesses and investigate the potential for shared urban mobility and freight delivery services to reduce congestion and emissions;
- Investigation of conceptual frameworks to support decision makers in analysing scenarios and solutions, helping them to make choices in a multi-criteria perspective and to define implementation roadmaps;
- The design of simulation models to evaluate the global performance services (in a multi-criteria perspective) and to analyse different scenarios in terms of demand and technology adoption evolution and generic models to capture the characteristics of the context (city, metropolitan area);
- Analysis of the impact of existing urban transportation policies and regulations on mobility and logistics integration and develop innovative policy frameworks that incentivise sustainable practices and collaboration between mobility and logistics stakeholders;
- Digital platforms that enhance communication and coordination between mobility and logistics stakeholders, including exploring innovations in IoT (Internet of Things) and other digital technologies and connectivity to improve traffic management, vehicle tracking, and real-time data sharing;
- Innovative financing mechanisms, such as public-private partnerships, green bonds, and crowdfunding, to fund sustainable urban transportation and logistics initiatives;
- Integration of SUMP and SULP efforts across neighbouring cities or regions to address cross-border and inter-city logistics challenges (e.g., the Øresund Region);
- Training programs and capacity-building initiatives to equip urban planners, policymakers, and logistics professionals with the skills needed to integrate SUMP and SULP effectively.

Results are expected to contribute to the following outcomes:

- Demonstration of effective planning and adoption of cross-sectorial and system thinking approaches and harmonisation with other related policy instruments, such as sustainability development plans, SUMPs, cycling and walking, dynamic urban planning and a multi-stakeholder and trans-disciplinary approach (e.g., social aspects);
- Alignment of the goals and objectives of these local policy instruments to create a shared vision for European urban areas to support streamlining decision-making and resource allocation;
- Support for cities in piloting real-world solutions at a significant number of living labs that should include innovative measures related to consolidation and public space management, new delivery models, data collection, and adoption of low/ultra emission zones (e.g., by UVAR) addressing urgent challenges (e.g., safety concerns, unnecessary journeys, illegal parking, conflicts with other transport – active - modes);
- Replicability and uptake in more cities situated in different Member States or Associated Countries;
- Smooth collaboration of a plurality of categories of stakeholders that need to be active players and involved in the planning and decision-making processes so that a wide range of interests and priorities can be embraced;
- Promotion of citizen participation at a neighbourhood or district level in sustainable transportation and logistics solutions to guarantee their needs and expectations are duly considered;
- Increase of societal readiness, for example, by measuring the acceptability of new mobility and logistics solutions and behavioural change from the consumers and people to make more sustainable choices;
- Demonstration of sustainable technologies developed in the 2Zero and CCAM partnerships, considering different types of AVs and the associated requirements in terms of infrastructure;
- Co-assessment and provision tools (with indicators related to SULPs – as SUMI for SUMPs) to cities so that they can identify the strengths and weaknesses of their urban logistics system and focus on areas for improvement. The assessment of the impacts of implemented measures needs solid methodologies for data collection and standardised indicators to become a reference for EU cities, as in the Urban Mobility Framework;
- Achieve cost savings and identify new revenue streams for logistics and transport players, increasing operational efficiency with lower operating costs and potential for growing new market share and competitiveness;
- Data-driven solutions that cities can implement to better address investments in terms of infrastructures and services;
- Sharing of data between mobility and logistics stakeholders to ensure that cities can identify synergies and optimise routes, reducing empty truck runs and minimising the overall environmental impact of goods delivery through the analysis of mobility and logistics data together.

SULPs are a priority topic (projects concluded by 2030) that requires a full call topic development.

4.4 Public involvement and co-creation

A sustainable, safe, and resilient built environment and mobility system needs the capacity and flexibility to manage the uncertainties and ambiguities arising from climate change, extreme weather events, as well as societal changes. This demands expert scientific knowledge and local knowledge; this knowledge comes together through cooperation, collaboration, and co-creation processes. Such approaches can help

raise citizen awareness, reveal vulnerability, complexity, and path dependencies, as well as promote the exploration of resilient and sustainable solutions and policies that facilitate sustainable mobility.

Over the years, it has become evident that changes to the current mobility system (i.e., re-allocating street space, prioritising alternative modes of transport) not only impact people's daily access to jobs, services and recreation but also profoundly influence their sense of identity. Even in the cases where there are net positive benefits for all parties, it can still be difficult for people to truly understand the long-term implications of what a different mobility system could look like – and equally importantly, to feel that they have some control and ownership over how that will impact their way of life.

Thus, very human-centric approaches towards public involvement are critical for sustainability and long-term success in mobility changes. That includes understanding people's sentiments on the ground and ensuring the changes are designed in the best way possible to correspond with people's needs, expectations and complex everyday realities. While public involvement approaches often relate to more traditional consultation processes, which are valuable but less in-depth, co-creation involves true collaboration in devising and implementing measures.

In many instances, this is also new territory for public authorities responsible for leading the change. On the one hand, it requires strong political will to counter resistance, unpack and address, if needed, the reasons for it, and uncover public support (e.g. the silent majority). On the other hand, it demands great technical execution that considers people's existing behaviours, abilities, perceptions, and knowledge to make the change as clear and smooth as possible, also requiring closer collaboration between departments than is usually the case in traditional mobility and urban planning processes.

When done systematically, with inclusivity and accessibility principles, public involvement and co-creation can lead to two major long-term benefits: 1) building trust among the public in the decisions made and implemented for mobility and urban planning, and 2) improving cross-departmental cooperation within the local authority and fostering trust internally.

Living labs and co-creation are valuable tools for innovation and urban development, offering the potential to test and refine solutions in real-world contexts. Addressing these challenges often requires careful planning, strong and trustful partnerships, a genuine appreciation of otherness, authentic dialogue, a commitment to ethical and user-centric approaches, skilled staff, time, and money. While co-creation tools offer numerous benefits for innovation and urban development, they also come with some challenges.

Many of the tools for co-creation and public involvement already exist and have been well researched – there are tried and tested models that would benefit from applied dissemination. The critical need is for public authorities, in some instances in partnership with academic/research institutions and local NGOs, to gain hands-on experience to apply and adapt these tools to their specific context and needs.

There is a niche need on how to specifically apply these tools to urban mobility, including mobility pilots that are funded through the R&I agenda. This expands the repertoire of public engagement beyond traditional mechanisms and requires skills in User Experience (UX) and user testing, quick and agile feedback loops, and cooperation between cities/companies/start-ups to develop and evaluate pilots from a citizen perspective. Many of these techniques are grounded in human-centred design and ethnographic research principles.

There is also the opportunity for further innovation in the application of virtual reality, digital twins, AI image generators, and other digital tools that help people to visualise and immerse themselves in alternative futures that are superimposed on their surrounding environment. This is important to help people provide meaningful input into design scenarios, street sections, etc., that do not yet exist.

Further, given the controversial nature of topics such as parking management and public space reallocation, more well-documented processes and examples of how to apply co-creation and public involvement to these and other specific topics would be welcomed. Also needed is better empirical knowledge about the potential of alternative conflict resolution approaches, esp. for emotionally laden topics where interest-based negotiation and consensus building techniques can possibly go beyond the usual impasse and reflex-oppositions.

Finally, while not directly related to co-creation and public involvement, more attention can be paid to education and behaviour change techniques to take advantage of “low-hanging fruits” where people may already be willing to employ more sustainable mobility practices if provided with sufficient guidance and communication. Operators and local authorities should create smart nudging mechanisms and offer incentives to their customers for supplying information as part of this value co-creation paradigm. Community-based approaches based on the mobility-as-a-commons principles should be thoroughly tested and evaluated at a larger scale.

The deployment of the right methodological framework and support tools should foster public involvement, encompassing all groups of people, regardless of their current use (or non-use) of certain transport services, as a way to capture citizens’ expectations and needs, to explore new mobility opportunities, and to decrease social exclusion.

R&I activities should include:

- The development of tools to support implementation roadmaps, promoting all social group’s participation, the co-design, co-implementation and co-evaluation of new services, and the adoption of more sustainable mobility habits;
- The design of inter-disciplinary conceptual frameworks to support the set-up and deployment of tools to support co-creation initiatives;
- Integrating public involvement and co-creation into mobility pilot projects, with a focus on co-creating requirements, understanding the user experience and citizen evaluation of the pilots;
- Documentation on co-creation and public involvement processes, with possible digital platforms for feedback;
- Research on incentives / nudging mechanisms to foster and frame public participation and the involvement of people in co-creation initiatives;
- Application of virtual reality, digital twins, AI image generators and other digital tools to help people visualise and immerse themselves in alternate futures;
- The design and experimentation of new forms of democratic participation and people’s engagement, e.g., urban mobility design workshops, community visioning sessions and co-design spaces, virtual reality simulations, hackathons and innovation challenges, public art and place-making, storytelling and advocacy campaigns, educational initiatives;
- Training and capacity-building programmes to apply co-creation and public involvement techniques in cities, tackling issues of available resources, time constraints and delivery of results;
- Development of a common structure (categories, topics, guiding questions) for gathering info and documenting lessons learned.

Results are expected to contribute to the following outcomes:

- More sustainable, efficient, and equitable transportation systems that benefit communities by addressing their specific needs and priorities, with public involvement playing a key strategic enabling role;
- More user-centric transportation systems that are convenient, efficient, safe, secure, welcoming and accessible and that also cater for specific vulnerable transport users, such as recently immigrated people, ethnic minorities, low-income residents, children and older people, people without a driving licence, LGBTIQ+, caregivers and disabled people;
- Reduced traffic congestion, enhanced subjective and objective safety and improved accessibility;
- Easily scalable and customisable methodologies and tools to frame and foster public involvement and co-creation, and guidelines and tools to support the analysis of scenarios and solutions, defining realistic implementation roadmaps;
- Delivery of the goals set out in the European Commission's Research and Innovation Strategy 2020-2024, especially:
  - Environment and climate, to act quickly and firmly to help restore ecosystems, give space to nature and radically transform how we do things;
  - Protecting our citizens and our values, especially improving and protecting people's health at all ages; this includes protection from harm (noise, pollution, etc.) as well as – and explicitly so – the promotion of healthy daily routines (in particular, active mobility) and the promotion of mental health through social interaction in public spaces;
  - Democracy and rights, to develop innovations, policies and institutions to support democratic processes and enhance trust in democratic institutions.

Co-creation and public involvement are considered priority topics (projects concluded by 2030) requiring full-call topic development.

4.5 AI and modelling tools for better policy making and improved service design

AI has the capability to interpret data, assist judgments, and generate insights beyond human manual processing capabilities, including data-based predictions involving (but not limited to) congestion and safety-related issues. Different types of AI business models exist depending on the nature of a company's role (developers and adopters). Three major revenue models, including AI Application-as-a-Service, AI Infrastructure-as-a-Service, and AI technical and management consulting,[48] shed light on how AI companies develop themselves and engage with customers. Data collaboration is common among AI companies regardless of size, and a revenue-sharing model could facilitate this collaboration. European AI development and deployment is rapidly advancing. While AI is gradually advancing in, e.g., vehicle on-board application domains, it is far less developed for policy-making purposes. The technology-driven vehicle industry is keener to adopt AI and model-based solutions than local and regional authorities are.

[48] https://www.eiturbanmobility.eu/wp-content/uploads/2021/09/EITUM-UrbanMobilityNext3_Final.pdf

In the context of advancing AI, a transition to digital trustworthiness is a key policy driver. The European Commission's AI High-Level Expert Group has defined the following requirements for Trustworthy AI:

1) lawfulness (i.e., compliant with all applicable laws and regulations),
2) ethics (adhering to ethical principles and values) and
3) robustness (from a technical and social perspective to prevent unintentional harm).

To achieve this, a human-centric approach is crucial. By understanding user needs, dimensions of trustworthy AI can be derived. Further research is required to explore the explainability, privacy, ethics, and accountability of AI models and their integration into transport systems.

One example of the integration of AI into transport solutions is the AI TraWell project, co-funded by EIT Urban Mobility and run by a consortium including Fraunhofer, TU Eindhoven and University College London. It uses AI to create an app that optimises multimodal routes to fit travellers' preferences and well-being. In this case, AI helps provide predictive information about the different transport modes a user considers so each journey can be adapted to one's preferences. In addition, Cooperative, Connected, and Automated Mobility (CCAM) solutions will exploit AI, which is trained on large and diverse data sources involving vehicles, infrastructure, and behaviour of different user groups.

R&I activities should include:

- AI and model-based tools that can support public authorities in efficiently and effectively developing policy, providing insights on the practical consequences (including quantification) of potential measures;
- Approaches and building blocks for the development and implementation of (urban) mobility services, including multimodal travel routing;
- Tools supporting local authorities to use predictive capabilities with (real-time) data in real life traffic and incident management;
- Additional AI applications that maximise impact for reducing CO2 of urban transport (e.g., traffic and logistics forecasts, on-demand bus services, vehicle tracking on transport networks);
- Solutions tackling the existing high risk of cybersecurity, compliance, and personal privacy.

Results are expected to contribute to the following outcomes:

- Provide focus for the mobility sector, business leaders, and policymakers on three priority areas: investments in AI, data infrastructure & skills, and ethical & trustworthy AI;
- Link the mobility domain-specific knowledge and methods with the emerging approaches in the AI scientific community;
- Improve data infrastructure (data collection, storage, inter-operability/standards) and skills (capacity, education, awareness in the public & private urban mobility sector);
- Work with explainable AI, taking ethics and user aspects into account, including notions of fairness;
- Address perception (what the AI model perceives and why), situational awareness (having cognisance of the current driving environment), decision-making (the logic behind why a certain decision is taken) and traffic management (ensuring efficient movement of people and goods involving stakeholders equitably).

AI and modelling tools are considered a longer-term R&I issue.

Milestones for Frameworks and Enablers

Frameworks and enablers	Research and innovation topics	Type of action	Milestone
Governance and regulations	New governance models that enable physical proximity and digital connectivity for collaborative, integrated mobility	RIA	2030
	New governance and regulations for collaborative business models between public authorities, technology and mobility providers, urban logistics service providers, and real estate for data sharing and data-driven services	IA	2040
SUMPs	The development of “digital twins” of the main mobility processes involved in the geographical area under study, based on various forms of data and collected through multiple channels, exploring big data, modelling and monitoring tools for better services and policymaking	IA	2030
	The construction of a conceptual “framework” to support decision makers in analysing scenarios and measures, helping them to make choices in a multi-criteria perspective and to define implementation strategies, together with the design and experimentation of new forms of democratic participation and people’ engagement	RIA	2030
	The integration of other fields such as climate mitigation, climate change adaptation, energy, logistics, sustainable transition, inclusion etc.	IA	2030
SULPs	Data integration and analytics, including innovative methods for integrating mobility and logistics data to provide a comprehensive view of urban transportation and exploring data analytics and machine learning techniques to identify optimisation opportunities and improve decision-making	IA	2040
	Green and sustainable mobility and logistics technologies, including 2Zero and CCAM solutions and exploring the use of renewable energy sources and energy-efficient technologies in logistics operations	RIA	2040
	Study the design and effectiveness of Urban Consolidation Centres (UCC) in reducing the number of delivery vehicles in urban areas, including innovative UCC models with shared logistics and mobility hubs	IA	2030
	Explore platforms and applications that promote ridesharing, carpooling, and collaborative logistics among businesses and investigate the potential for shared urban mobility and freight delivery services to reduce congestion and emissions	IA	2030

Frameworks and enablers	Research and innovation topics	Type of action	Milestone
	Digital platforms that enhance communication and coordination between mobility and logistics stakeholders, including exploring innovations in IoT (Internet of Things) and other digital technologies and connectivity to improve traffic management, vehicle tracking, and real-time data sharing	IA	2030
Co-creation and public involvement	The development of tools to support implementation roadmaps, promoting all social group's participation, the co-design, co-implementation and co-evaluation of new services, and the adoption of more sustainable mobility habits, with inter-disciplinary conceptual frameworks to support the set-up and deployment of tools	IA	2030
	Application of virtual reality, digital twins, AI image generators and other digital tools to help people visualise and immerse themselves in alternate futures, with the design and experimentation of new forms of democratic participation and people's engagement	IA	2040
	Training and capacity-building programmes to apply co-creation and public involvement techniques in cities, tackling issues of available resources, time constraints and delivery of results	IA	2030
AI and modelling tools for better policy making and improved service design	AI and model-based tools that can support public authorities in efficiently and effectively developing policy, providing insights on the practical consequences (including quantification) of potential measures	RIA	2040
	Additional AI applications that maximise impact for reducing CO2 of urban transport (e.g., traffic and logistics forecasts, on-demand bus services, vehicle tracking on transport networks)	RIA	2050
	Solutions tackling the existing high risk of cybersecurity, compliance, and personal privacy, with improved data infrastructure (data collection, storage, inter-operability/standards) and skills	IA	2030

Table 1 Frameworks and enablers – milestones

5 RESEARCH NEEDS, PRIORITIES AND MILESTONES – INNOVATIVE URBAN MOBILITY SOLUTIONS AND SERVICES

The solutions and services outlined in this chapter will focus on research topics within four fields:

5A. Infrastructure-related solutions

5B. Service-related solutions

5C. Management-related solutions

5D. Modal solutions

5A. Infrastructure-related solutions

5.1 Built environment as part of the mobility system (people and goods)

Mobility systems and the built environment have a complex and important relationship. Built-up areas, infrastructures, the design and layout of neighbourhoods, roads and streets - even the position, management and design of buildings – significantly impact mobility systems. These factors also impact people's choices and habits with regard to trip frequency and length and travel mode. The difference between sprawling single-family neighbourhoods and contemporary "car-free" districts demonstrates this effect dramatically. The real-estate sector, therefore, needs to be increasingly included in efforts to move towards more sustainable mobility systems.

With the increase in extreme weather events and the impacts on a growing number of users, it is essential to pay close attention to the functional relationship between the built environment and mobility systems to ensure alignment in resilience planning and climate change adaptation. Understanding and effectively managing the relationship between the built environment and mobility systems is critical in creating liveable, sustainable, and inclusive cities and mobilities.

Blue and green infrastructure, sustainable building practices, green spaces, and environmentally friendly infrastructure will not only boost sustainable mobility systems but support their operation and resilience. In addition, digital technologies and smart city initiatives are also key enablers for more sustainable and connected mobility systems, with improved mobility management, charging infrastructures, new services, etc.

Space is increasingly becoming a scarce and disputed commodity in urban areas. Many cities are rightly giving the urban space back to residents, reallocating and redesigning public space to improve quality of life and facilitate more active modes or to provide vegetation, shade, cooling, and water retention, among other things. In order to adapt to the climate crisis, space should also be allocated/reallocated to include

blue and green infrastructure. This results in a clear imperative to explore more space-efficient mobility, with prioritisation of PT, shared schemes (e.g. e-cars, LEV, micromobility), and active modes.

Space for mobility is not only about the mobility of people but also of goods and vital services. There are two primary streams of mobility in cities: the mobility of people and the mobility of goods and services, which need to go hand in hand without causing conflicts. The mobility of goods includes not only what is coming into cities, but also goods produced within the city and waste going out. The accessibility to other vital services, such as emergency and care vehicles, is also a factor. Buildings and the built environment need to be considered and adapted for these streams of mobility in cities.

Another growing and challenging contradiction facing the relationship between the built environment and mobility is the timespan considered when planning for functions and capacity. The built environment, with roads, infrastructure and buildings, is built for a time horizon of 50 or even 100 years. But traffic, mobility, and communication flows, especially automated solutions, have short time frames of seconds and milliseconds. Thus, harmonising and reconciling these differences and conflicts in time ranges of the built environment and mobility is increasingly crucial for resilient and sustainable systems. For instance, queries such as how compatible the roads, infrastructure and buildings built today will be with the mobility of the future needs to be addressed when looking at the resilience and sustainability of systems. This is not only a design challenge but also an operational and management challenge as exemplified by centralised, above-ground neighbourhood garages (as opposed to underground garages in every individual building complex). The former can be much more easily adapted to changing circumstances, such as new charging technologies, than the latter.

There are various challenges to be met, but also opportunities to explore how mobility systems can support the built environment and vice versa. Holistically developing governance, policies, technologies, innovations and new incentives for altered habits by bridging the gap between transportation and urban planning will be crucial in tackling challenges and harnessing opportunities.

R&I activities should include:

- Exploration of new building techniques, design principles and management that would bring flexibility to adapt to different uses during the lifespan of built infrastructure that would respond to mobility system changes and flows;
- Investigation on how to regulate, allocate and use the urban space in a climate-adaptive manner, considering access, design, management, planning and co-creation, to harmonise the mobility flows of people, services and flows;
- Experiment and adaptable mobility hubs where, for instance, people can easily pick up (or send) parcels and other types of goods, while at the same time managing other mobility needs (school runs etc);
- Exploration of different possibilities and types of dynamic space management and dynamic kerbside management that allow for the coordination of place and mobility of people and goods;
- Assessment of the coherence between policies and technologies to support and align the built environment and mobility systems and the role that industry, research, government, and civil society have to play in it;
- Better understanding of the structural incentives for real estate developers (Environmental, social and governance, social expectations, building standards, etc.) to develop residential and commercial buildings and neighbourhoods that facilitate a high share of active modes, PT, vehicle and ridesharing;

- Delivery of more objective information and higher awareness of the co-benefits of changes to the allocation, design, management, and use of urban space in terms of social cohesion, quality of life, happiness, public health, biodiversity, etc.;
- Development and testing of approaches to predict (ex-ante) and assess (ex-post) the impact of innovative building and neighbourhood design on mobility patterns, social cohesion, user satisfaction, public health, etc.;
- Study of the changes needed in knowledge, education, incentives, institutional structures, reward systems, etc., from industry, research, government, and civil society to move from business as usual to new innovative approaches to the constructed areas, structures, roads and streets to enable sustainable and resilient mobility systems;
- Development of frameworks for integrated planning workflows to address diverse target groups from the mobility and built environment for informed decision making;
- Monitoring and assessment of performance and impacts of actions and measures that align and reconcile the built environment and mobility systems towards resilience and sustainability, considering what types of vehicles are needed for a circular material, and people flow.

Results are expected to contribute to the following outcomes:

- Improved actions across actors and institutions for climate change adaptation and resilience of the built environment as part of the mobility system;
- Mobility systems and built environments harmonised and adapted to consider the different flows of people, goods and services entering, staying in and leaving cities;
- Mobility systems and built environments reconciled, with flexible uses addressing changes and different paces;
- Improved adaptation pathways to manage uncertainties over time;
- Improved visualisations and storytelling to raise awareness and promote actions;
- Higher level of factual information and awareness of the space consumption of a mobility system based on individually owned cars with low average occupancy rates.

Built environments - as part of the mobility system is a longer-term R&I topic.

5.2 Mobility networks infrastructure

All industrial sectors in Europe will require rapid decarbonisation to meet net-zero targets set for 2040 - 2050, depending on the EC Member State. Already, around 1 in 5 road vehicles sold are either hybrid or fully electric, with proposed bans on the sale of new internal combustion engine (ICE) light vehicles in European countries from 2025 – 2035. Whilst no firm target is set, a notional date of 2040 has been suggested for the transition of heavy vehicles to carbon-neutral fuels.

Research scopes will have to cover the implications and opportunities resulting from the energy transition and depletion of fossil fuels in transport infrastructure. Given that the energy transition will have implications across both vehicles and construction, these scopes need to cover all aspects of the transport cycle from the design, construction, operation, maintenance and recycling. This includes construction materials, techniques, plant energy options, light and heavy vehicles, and business models. Given the

wide range of actors involved, R&I activities must include industry, urban councils, national infrastructure operators, academia and research organisations.

R&I activities should include:

- Development of a catalogue of monitoring systems for infrastructure, together with case studies to examine the potential for life extension and carbon savings;
- Production of a definitive guide on whole-lifecycle carbon costs for a variety of mobility infrastructure options to cover construction and maintenance across the infrastructure cycle. This should include options for the circular economy;
- Review of infrastructure requirements for light vehicles, with a focus on safety "hot spots" to enhance vehicle safety, especially in transitioning from L7e to M1 categories, including evaluating electrification targets, static/dynamic charging options, hydrogen, and fossil fuel alternatives like biofuels and e-fuels
- Monitoring of transport infrastructure using big data technologies from various traditional monitoring techniques and new sources, including mobile phone data, probe vehicle data and data collected from connected vehicle data. Understand the potential of vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle (I2V) capability and infrastructure owner data. Development of validation models to assess how the data can be used together to determine trends in infrastructure deterioration.
- Development of a resource exchange mechanism for the reuse, repair and recycling of all types of transport infrastructure. This will consider the optimum position of facilities and mechanisms, including blockchain, to track materials entering, being stored, processed and leaving the facility.

R&I activities need to deliver practical solutions for the future of mobility in a fossil fuel-free or fossil fuel-reduced future.

Results are expected to contribute to the following outcomes:

- Roadmap for the future energy mix of light vehicles and required energy infrastructure;
- An assessment of options for the electrification of heavy vehicle (trucks/buses/coaches) fleets, specifically around the viability of electrical road systems or battery options.

Mobility networks infrastructures are considered a priority topic (projects concluded by 2030).

5.3 Urban construction

With urban areas concentrating population, energy consumption and CO2 emissions, most cities are encouraging fossil-free mobility of people and goods, but the construction segment has often been neglected. Europe's construction industry is vital for the economy, contributing between four and seven per cent of the GDP in 2022. It generated around 1.7 trillion euros in revenue in 2020, with specialised construction accounting for the largest portion of that turnover.

A significant and resource-intensive part of the construction process consists of transport to and from construction sites. Transport related to construction works make up a large proportion, 20-30%, of total urban freight transport. For instance, in Sweden alone, approximately 50% of urban transport is related to

construction work, affecting city congestion[49]. Transport work carried out in the construction sector is often a forgotten environmental issue, accounting for about 10-15% of the entire transport sector's emissions (in the case of Sweden, up to 4–5% of Sweden's total CO2 emissions), and this is forecasted to increase as a result of urban development.

Cities today face challenges not just from emissions and congestion, but also from the need to utilise urban space more efficiently and create safer streets. Construction sites are hazardous, with constantly changing environments and many human/machine interactions. Moreover, ensuring the transport and mobility of workers and the people involved in constructing and maintaining the built environment in cities is crucial to preserving the sector's viability and mobility sustainability. It is essential to consider that sustainability in mobility does not hinder the access of individual workers and small businesses in construction and maintenance (e.g. plumbers, painters, electricians) or their ability to perform their work in urban areas. Solutions for parking, urban vehicle access regulations and different types of low-emission vehicles and their affordability should consider the construction and maintenance workforce.

R&I activities should include:

- Development real-time connected worksites, transport and city infrastructure to decrease congestion – combining infrastructure capacity data & visualisation of mobility flows, with possible Construction Consolidation Centres "CCC";
- Development of new digital tools and services with digital traffic rules, smart traffic zones, vehicle-to-X (V2X), and C-ITS to manage the construction and maintenance workforce mobility and accessibility
- Development of smart technologies, tools and interaction with the different worksite stakeholders for control of points of access to worksites to increase road safety, particularly for pedestrians and cyclists

Results are expected to contribute to the following outcomes:

- Improved accessibility for the construction and maintenance workforce, especially for small businesses and individual workers with viable governance arrangements for managing the transport network and traffic to support other regulatory and political actions
- Increased safety on entry/exit to worksites with special attention to the safety of people walking and cycling and overall neighbourhood noise and pollution disturbance reduction.

Mobile non-road machinery urban construction is a longer-term R&I issue.

5.4 Mobility data infrastructure

Enhanced safety, reduced congestion, optimised traffic flow, improved transportation systems, and the promotion of sustainable mobility solutions are among the objectives of a robust mobility data infrastructure. It can achieve these objectives by fostering a comprehensive knowledge base accessible to mobility stakeholders, decision-makers, and potentially the general public (e.g. in the form of comprehensive and user-friendly mobility dashboards). The use of mobility data encourages the creation of smart cities and makes it easier to put cutting-edge transportation services and policies into place that meet the changing needs of city dwellers. Mobility data infrastructure - such as data spaces - will facilitate

[49] https://doi.org/10.1016/j.rtbm.2022.100830

the voluntary, sovereign, and secure sharing of data so as to foster collaboration between different departments and relevant stakeholders and enable new public and commercial business models and services while respecting usage control and privacy for data owners. Robust mobility data infrastructure enables data-based planning, thus allowing for more agility and adaptability of mobility services.

Table 2 is an extract from ERTRAC's "New Mobility Services Roadmap", Chapter 5, "Digital infrastructure and data management", which provides an overview of the research and innovation needs identified[50].

EU Research & Innovation needs with regards to digital infrastructure and data management		
Innovative tools for data management and application for traffic management	1.	Conduct further pilots and capacity building actions for the integration of NMS into traffic management, prioritisation of the most sustainable and accessible modes, and to address identified challenges
	2.	Include the context of multimodality and multiplication of available services in indicators defined for cities to monitor the efficiency of their transport policies and their impact on citizens' quality of life
	3.	Conduct more research and trials to make the digital collaboration between cities and operators sustainable and use the potential offered by data to the fullest
	4.	Enrich current research on decision support systems with new algorithms, to use it in a wider domain than public transportation, namely the management of urban mobility including NMS, also taking recently emerged challenges into account, such as sanitary conditions, increased demand for active travel and new user behaviours
Digital infrastructure governance	5.	Research, test, and conduct validation processes for models and principles of data control, data treatment through algorithms, and the structure of governing bodies
	6.	Conduct research and innovation actions on governance and accountability of control of data and structure of the governing body based on recommendations from previous research in the framework of the Sustainable Mobility for All initiative
	7.	Conduct targeted research on algorithms, based on recommendations from previous studies (e.g., ITF 2019 report on algorithms)
Data sharing approaches and technical innovations	9.	Support the definition of the right timing for sharing data according to the data identification
	10.	Encourage the set-up of a data-sharing culture
	11.	Keep outcomes of recent initiatives on data and use cases typologies up to date and most adapted to local contexts through pilot projects and best practices exchanges
	12.	Identify the most suitable European data specifications and standards for the purpose of regulation and data exchange, and further develop them
	13.	Conduct further pilot projects and communication to spread awareness of existing technologies enabling data sharing and related regulatory opportunities

[50] https://www.ertrac.org/wp-content/uploads/2022/07/ERTRAC-New-Mobility-Roadmap-V4.pdf

EU Research & Innovation needs with regards to digital infrastructure and data management		
Enabling MaaS	14.	Build capacity and empower local and regional authorities to define a clear vision and strategy for MaaS, leveraging transport operators and defining the parameters and objectives of a MaaS system
	15.	Communicate on the features required for the MaaS System, and conduct pilot tests of different models, as there will not be a single model for all European cities and regions
	16.	Analyse the different proposals of MaaS models emerging, their pros and cons, and the respective roles of the public and private sector
	17.	Encourage local level definition of business models and cooperation models between operators and public authorities, also for the inclusion of additional services in MaaS

Table 2 Research recommendations on digital infrastructure and data management (Source: New Mobility Services Roadmap, v4, 2021, pp23-24)

According to an EIT Urban Mobility expert survey, open data, although clearly valuable, will not be sufficient to address the data needs of future mobility. Data spaces are designed to bridge this gap, providing trusted, secure ecosystems to share more sensitive data and integrate today's evolving collection of open data sources. Moreover, data spaces facilitate data-driven decision making and increase compliance with privacy and security regulations.

For a city to be competitive in the race against climate change and in reducing transport emissions, it must develop the capacity to facilitate, manage, analyse and use the power of urban transport data in ways that support its climate objectives. Appropriate mobility data infrastructure will bring structure and transparency to understanding the behaviours and needs of people. Collecting and evaluation mobility data can facilitate data-based planning and the monitoring of sustainable mobility measures. This enables more efficient cooperation between municipal actors, as well as with private stakeholders. This data forms the foundation for more efficient mobility models such as MaaS and smart logistics. So far, they have seen their progress inhibited by fragmented data sharing between value chain actors in the mobility sector.

One of the critical challenges facing mobility data spaces is their early-stage status as a data marketplace, and currently, the lack of a clear and financially self-sustaining business model. Although government backing reinforces the development of mobility data spaces, only facilitating data sharing is not a financially viable proposition for mobility data spaces. Other solutions must be incorporated to generate and maintain adequate revenue. Furthermore, challenges exist in developing, deploying, and operating these spaces and in the commercialisation aspects of transitioning from conceptual design to piloted innovation to a sustainable in-production service model.

The transition to the digital economy requires investment in technology upgrades and increasing knowledge to facilitate well-informed and strategic decision making.

R&I activities should include:

- Development of innovative methods for integrating mobility and logistics data;

- Creation of protocols for standardising and integrating various data formats, also with facilitation of seamless integration with existing infrastructure, platforms, and accessibility by multiple types of stakeholders;
- Development of skills and capacity-building pathways, leveraging mobility data infrastructure to support the planning of sustainable transportation systems;
- Development of governance tools and standards ensuring privacy and data protection to enhance cooperation and confidence among all stakeholders of urban mobility value chains;
- Structuring of use cases into Minimum Viable Product implementation phases that act as short and mid-term demonstrators to start iterating the business scope, technical approach, and governance model;
- Development of a roadmap for future service offerings and pricing options that incentivise private sector participation in mobility data spaces;
- Integration of mobility data spaces with advanced digital twin cities to maximise the potential impact of both technologies;
- Conducting further research on identifying relevant data sets for sustainable mobility, interpreting data to develop new planning approaches and strategies, and monitoring their implementation and success factors based on data;
- Mainstreaming of data justice, including demographically differentiated data gathering, i.e. better empirical knowledge of the mobility needs and patterns of women, children, older people, etc.

Results are expected to contribute to the following outcomes:

- Increased data sharing between mobility and logistics service operators and providers to minimise the overall environmental impact of goods delivery through the analysis of mobility and logistics data together;
- Engaged stakeholders, delineated data-sharing governance and data justice;
- Defined appropriate governance and collaborative business models for running data spaces;
- Improved local authority capacity in the managing and collection of data and awareness in the public & private urban mobility sector;
- Established connections with other sectoral data spaces;
- Defined common standards, including semantic standards and interoperability protocols, both domain-specific and crosscutting.

This topic is a longer-term R&I issue.

5.5 Energy infrastructures for clean fuels and vehicles

In order to move toward sustainable transportation systems, energy infrastructure for clean fuels and vehicles is crucial. They must be made comprehensive and robust. Collaborate between governments, industries, and communities is crucial to address cost, technology, and infrastructure deployment challenges. The information below builds on the document “A Mapping of Technology Options for

Sustainable Energies and Powertrains for Road Transport: Towards Electrification and other Renewable Energy Carriers" created by the ERTRAC Energy & Environment working group[51].

To ensure the EU Green Deal's success, it is crucial to have widespread access to recharging, battery swapping, and refuelling infrastructure for alternative and clean fuels. The availability of charging infrastructure is a significant concern for cities and electric vehicle users. By 2030, approximately 33 million electric vehicle users in Europe – including both private and shared mobility – will require efficient charging. Upgrading the electric grid while minimising the necessary reinforcements, such as grid reliability, load accommodation, and integration of renewable energy sources, is essential to meet the expected increase in electricity consumption due to electric vehicles. Innovations in smart technology, such as smart charging, vehicle-to-x (where x can be any load such as homes, buildings, parking garages, etc.), and vehicle-to-grid (V2G) can help manage energy and clean fuel demands effectively through real-time energy consumption and flow monitoring, alongside grid reliability, accommodating higher loads, and integrating renewable energy sources.

With a goal to achieve net zero greenhouse gas emissions and manage an annual local or regional surplus production of renewable energy, Positive Energy Districts (PED) are innovative urban areas designed to be energy efficient and flexible. Different systems and infrastructures need to be integrated, and there must be interaction between buildings, users, and regional energy, mobility, and ICT systems. It is important to ensure a secure energy supply while also promoting social, economic, and environmental sustainability[52]. Combining non-energy services like electric shared mobility with the PEDs offers the advantage of reducing stress on the electric grid and harmonising the peaks by better managing the demand at the neighbourhood level by using electric vehicles as mobile battery storage systems and integrating renewable energy sources into the functioning of buildings.

To further accelerate the development and deployment of clean energy infrastructure in the mobility sector, governments at all levels, including cities, regions, nation-states and Europe, need to pay special attention to targeted long-term policy frameworks, investments in integrated transport and energy infrastructure, and standardised data collection from operational infrastructure to monitor the realisation of policy objectives.

R&I activities should include:

- Development of governance tools and standards to enhance cooperation and confidence among all stakeholders of urban mobility value chains with smart funding mechanisms and stable policy framework to increase investment security for investors;
- Provision of startup support through pilot projects, reverse pitches, access to hardware, prototype facilities and operational data;
- Establishment of proven concepts and pilot activities of Positive Energy Districts encapsulating the complementary mobility measures such as shared mobility configurations, vehicle access regulations and multimodal and energy hubs.

[51] https://www.ertrac.org/wp-content/uploads/2022/12/ERTRAC-Fuels-Powertrains-Research-Needs-Mapping-Final-Version-December2022.pdf
[52] https://jpi-urbaneurope.eu/ped/

Results are expected to contribute to the following outcomes:

- Integration of transport and energy infrastructure to better optimise the efficiency of using existing infrastructure while minimising the need for investments and to reduce individual private mobility and enhance the value of shared mobility;
- Better understanding of the planning behind setting up infrastructure, whether it is recharging or refuelling, power requirements or grid-related issues;
- Optimised use rates of charging points and stations – including technological standardisation to improve refuelling infrastructure coverage – while eliminating uncertainties linked to their accessibility;
- Adaptation of the charging infrastructure setup by understanding the charging habits and other socio-demographic and socio-cultural aspects of end users.

This topic is a longer-term R&I issue.

MILESTONES FOR INFRASTRUCTURE-RELATED SOLUTIONS

Infrastructure related solutions	Research and innovation topics	Type of action	Milestone
Built environment as part of the mobility system (people and goods)	Explore different possibilities and types of dynamic space management and dynamic kerbside management that allow for the coordination of place and mobility of people and goods	IA	2030
	Investigate how to regulate, allocate and use the urban space in a climate-adaptive manner, considering access, design, management, planning and co-creation, to harmonise the mobility flows of people and services	RIA	2040
	Assess the coherence of policies and technologies to support and align the built environment and mobility systems and the role that the industry, research, government and civil society have to play in enabling changes in the allocation, design, management and use of urban space in terms of social cohesion, quality of life, happiness, public health, biodiversity, etc	CSA	2040
	Study the changes needed in knowledge, education, incentives, institutional structures, reward systems, etc., from industry, research, government, and civil society to move from business as usual to new innovative approaches to the constructed areas, structures, roads and streets to enable sustainable and resilient mobility systems	RIA	2030
	Monitor and assess performance and impacts of actions and measures that align and reconcile the built environment and mobility systems towards resilience and sustainability, considering what	RIA	2030

Infrastructure related solutions	Research and innovation topics	Type of action	Milestone
	types of vehicles are needed for a circular material and people flow		
Mobility networks infrastructure	Develop a catalogue of monitoring systems for infrastructure aligned with a guide on whole-lifecycle carbon costs of mobility infrastructure, with case studies for life extension, carbon savings and circular economy	CSA	2030
	Review infrastructure requirements for light vehicles, with a focus on safety "hot spots" to enhance vehicle safety, especially in transitioning from L7e to M1 categories, including evaluating electrification targets, static/dynamic charging options, hydrogen, and fossil fuel alternatives like biofuels and e-fuels	CSA	2030
	Monitor transport infrastructure using big data technologies from various traditional and new sources. Understanding V2I and I2V capability, infrastructure owner data, and developing validation models to assess data for determining trends in infrastructure deterioration	RIA	2040
	Develop a resource exchange mechanism for the reuse, repair and recycling of all types of transport infrastructure.	IA	2040
Urban construction	Develop new digital tools and services with digital traffic rules, smart traffic zones, vehicle-to-X (V2X), and C-ITS to manage the construction and maintenance of workforce mobility and accessibility	IA	2040
	Develop smart technologies, tools and interaction with the different worksite stakeholders for control of points of access to worksites to increase road safety, particularly for pedestrians and cyclists	IA	2040
Mobility data infrastructure	Governance tools and standards ensuring privacy and data protection to enhance cooperation and confidence among all stakeholders of urban mobility value chains;	RIA	2030
	Skills and capacity-building pathways, leveraging mobility data infrastructure to support the planning of sustainable transportation systems;	IA	2030
	Mainstream demographically differentiated data gathering, i.e. better empirical knowledge of the mobility needs and patterns of women, children, older people, etc	RIA	2040
	Creation protocols for standardising and integrating various data formats, also with facilitation of seamless integration with existing infrastructure, platforms, and accessibility by multiple types of stakeholders, with integrated mobility data spaces	RIA	2030

Infrastructure related solutions	Research and innovation topics	Type of action	Milestone
	with advanced digital twin cities to maximise the potential impact of both technologies		
Energy infrastructures for clean fuels and vehicles	Governance tools, standards, smart funding mechanisms and stable policy framework to enhance cooperation and confidence among all stakeholders of urban mobility value chains	RIA	2030
	Provide startup support through pilot projects, reverse pitches, access to hardware, prototype facilities and operational data	IA	2040
	Establishment of proven concepts and pilot activities of Positive Energy Districts encapsulating the complementary mobility measures such as shared mobility configurations, vehicle access regulations and multimodal and energy hubs	IA	2040

Table 3 Infrastructure-related solutions: milestones

5B. Service-related solutions

5.6 New mobility services

The 2021 ERTRAC *New Mobility Services Roadmap* provides valuable content and input to this section, where research priorities are being revisited and revised to reflect the present context. Daily mobility in urban, peri-urban and rural areas is strongly changing with the provision of numerous new services, strongly based on more complex multimodal systems (with new and shared mobility services), along with the "digital transformation" and the generalised adoption of mobile devices by citizens.

Within the growing spectrum of new mobility services, it is possible to highlight two main categories:

- Ride-based services or on-demand mobility: this includes services such as demand-responsive transport, ride pooling, micro-transit, ride-hailing and taxis, as well as carpooling (with a potential for automation);
- Fleet-sharing services or shared vehicles: this includes services such as shared cycles, e-scooters, mopeds, cars and others, as well as vehicle rental.

Considering these two main categories, there is a need to explore their optimum design in terms of user convenience, societal, environmental and economic value for the authorities and performance and business models for the operators. Moreover, it is relevant to understand their interrelations and their combination with mass public transport and active mobility, with the aim to complement and not undermine those. This is relevant for creating an integrated ecosystem to reduce people's dependence on single-occupancy vehicles.

In terms of service design, for the on-demand mobility family and, in particular, for demand-responsive transport, micro-transit and ride pooling services, the practitioner community recognises the need for an

international observatory and solid impact assessment based on standardised KPIs, where the different software providers should not push their own agenda.

When looking at shared vehicles, a better understanding of their optimal design, interrelations and optimal mix, especially in terms of different types of micromobility, could greatly support authorities in better shaping public policy and governance. In relation to carpooling, the service design is not fully mature yet, but there is a clear need to develop its capacity to increase the occupancy rate of private cars. The theoretical impact of the rise of vehicle occupancy rates is vast, but the real implications are not clearly studied nor applied to service design and public policies.

New mobility services and interventions in the infrastructure and the organisation of urban space can play a key role in achieving more sustainable and climate-neutral cities. These services could integrate dimensions of the 15-minute city, considering density, diversity, proximity, and digitalisation, to support broader sustainability goals in mobility and cities. The role of users in the design of mobility solutions must be reinforced, along with the participation of the other actors and stakeholders. Given the variety of actors and stakeholders involved, often with conflicting perspectives, such services should be designed based on multi-criteria approaches, thus emphasising the “trade-offs” and “values” conveyed by policies and regulatory frameworks.

Balancing and assessing the benefits and negative externalities of new mobility services is crucial. Currently, the growing attractiveness of these types of services can be detrimental to PT and active travel, sometimes with clear negative impacts, e.g., in terms of environmental sustainability or the use of the urban space. This is particularly the case when NMS are rolled out without a clear integration with conventional PT services, such as in dense urban areas. On the other hand, for instance, when NMS, such as on-demand services, are designed as feeder services to PT hubs, they allow for sustainable trip chains and more car-independent lifestyles.

Particular attention should be given to connecting remote and car-dependent suburban or rural areas with city centres through, for instance, well-integrated on-demand services, handling broader metropolitan areas, and addressing more problematic situations of social exclusion. For new mobility services to deliver their potential to people and cities, aspects of the fair twin transition should be considered.

R&I activities should include:

- Investigating the impact of the different governance models and the different features included, and communicating on research about NMS’ impacts on regulatory and governance frameworks;
- Surveying the position of current service providers and infrastructure managers in the urban space ecosystem to understand how current players can contribute to NMS, increased multimodality, and integrated city logistics and people’s mobility;
- Developing innovative financing models for NMS outside of dense urban areas so as to allow for car-independent lifestyles also in peri-urban areas (e.g. multi-purpose use of on-demand vehicles for different mobility and logistics purposes);
- Advancing the physical and digital integration and strategic planning of more complex, integrated mobility services that are strongly intermodal and dependent on multiple information layers and channels;
- Creating innovation accelerators at the local level, overseen by local authorities, allowing for the establishment of a common framework for all local innovations;

- Evaluating methods to assess the impact of NMS (e.g. modal shift, reduction of car ownership, creation of intermodal trip chains, etc.), including designing simulation “models” to evaluate the global performance of these services (in a multi-criteria perspective) at a system level and to analyse the evolution of demand and technology adoption;
- Developing co-creation tools and methods supporting implementation roadmaps, promoting people’s participation, co-designing new services, and adopting more sustainable mobility habits.

Results are expected to contribute to the following outcomes:

- Recommendations for planning, policies and regulatory frameworks that enable services responsive to cities’ and regions’ ambitions and needs;
- Roadmaps for implementation that consider different cities’ and metropolitan areas’ specific goals, available resources, needs and expectations of the multiple involved stakeholders;
- New business models and services that do not overlook sustainability, affordability, and equity, providing a platform for innovative start-ups;
- A variety of service models able to address both urban and peri-urban areas, as well as the urban-rural connection.

New mobility services are considered a priority topic (projects concluded by 2030), requiring development of a full call topic.

5.7 Next generation Mobility as a Service

MaaS encompasses multiple services in an integrated and customisable way and should aim at providing better accessibility, hopefully aligning purely commercial dimensions with better and more individual mobility in a more sustainable perspective. For this to fully deliver on societal goals, it is crucial to achieve an alignment of policies and incentives that reflect priorities in terms of mobility options (with walking, cycling, and public transport as cornerstones) from the national to local level. For example, more research should cover the impacts of policies to support scrapping private cars against a minimum mobility budget actionable through a MaaS scheme or similar or for employees to switch from company cars to other mobility packages.

The key advantage of MaaS is the advancement towards a multimodal lifestyle that better matches people’s changing mobility habits due to, for instance, trip purposes and time of the day. When properly and broadly implemented, MaaS holds the potential to provide a more convenient and attractive alternative to individual car ownership. Intelligent solutions to make MaaS more comfortable, reliable and safe will make it more attractive, and it could keep mobility affordable. Within the context of new mobility systems, it is critical to strengthen – and certainly not weaken – the quintessential role of public transport in decarbonisation, curtailing urban sprawl, and promoting social inclusion for all segments of society.

The success of MaaS relies greatly on the quality of mobility options and it should participate in the improvement of those services as well as their multimodal combinations by sharing valuable data with those who participate in the scheme, as well as with authorities. Data governance is essential for good MaaS schemes.

R&I activities should include:

- Building capacity and empowering local and regional authorities to define a clear vision and strategy for MaaS, leveraging transport operators and defining the parameters and objectives of a MaaS system;
- Developing an international observatory of MaaS schemes, a solid assessment and a general understanding in the practitioner community of the benefits and impacts of different MaaS implementations for different stakeholders, including users;
- Exploring different governance models for a public policy-driven MaaS;
- Examining and developing different and new business models for MaaS, that can cover different urban and peri-urban contexts;
- Developing data-sharing protocols between public and private entities and among private entities to build a MaaS ecosystem;
- Developing and assessing the integration of MaaS with other service models that could address cities' broader climate neutrality and social goals (e.g. inclusivity and accessibility);
- Investigating, developing and assessing MaaS schemes and services that can cater to a diversity of users, considering affordability, physical accessibility, different usage needs and coverage.

Results are expected to contribute to the following outcomes:

- Improved MaaS systems that can cater to a wide variety of users and uses, including different geographies, contexts, and population sizes;
- Cities, regions and other public authorities empowered with clear autonomy and governance over MaaS systems that align with broader sustainable and economic goals.

Next generation Mobility as a Service is a priority topic (projects concluded by 2030), requiring development of a full call topic.

5.8 Urban freight and logistics

Urban logistics encompasses the entire transport system focused on functional urban areas, including cities, metropolitan areas, clusters of municipalities, and catchment areas. This system includes the last-mile delivery of goods and e-commerce to retail outlets or private residences, and all necessary urban service-related activities that, if not adequately planned and managed, drastically affect urban life (waste collection, road maintenance, public and private construction sites, etc.) and the trades (home maintenance, repairs, product installations, furnishings, etc.).

Efficiently planning and managing such a complex urban freight system requires reconciling the provision of these services, and recognising their genuine value, along with the negative externalities stemming from the unbalanced allocation of scarce urban space and transport infrastructure systematically interacting with people's mobility.

As urbanisation continues to increase, the number of small or single-person households is also rapidly increasing. This has led to a growing demand for the delivery of more (and sometimes unnecessary) products in smaller quantities and dimensions compared to traditional shopping. Similarly, the number of returns is growing due to the common trend of free returns, especially in the fast-fashion market. Besides

these trends related to last-mile delivery, city service activities have a significant impact, especially in urban areas. This includes construction and waste logistics and the delivery of goods to local commerce. These trends result in increased traffic, further exacerbating conflicts between passenger and freight mobility, affecting flows and parking, and greatly contributing to urban traffic congestion and pollution.

This significant increase in freight vehicles in cities increases the competition for parking spaces, reducing accessibility due to “temporary” parking, and adds to general road congestion - leading to increased home delivery costs and collisions involving commercial vehicles and pedestrians and cyclists. While the shortage of loading and unloading areas for delivery vehicles is evident, it is not feasible to permanently transform cities into massive, dedicated parking lots. Therefore, there is a need to develop new models for planning and sharing urban space through improved overall governance in the organisation and management of resources and functional city needs. And the dynamic use of urban space, with diverse functions according to differing needs throughout the night and e.g. dynamic kerbside management.

The lack of coordination between businesses and public authorities in the area of urban logistics can exacerbate the negative externalities of these services and hinder their role in economic growth and social activities. The lack of collaboration hampers the transition to cleaner and more efficient logistics practices. From the business perspectives, excessive and uncoordinated logistics activities, besides disrupting residents' and workers' quality of life, can lead to conflicts between businesses and the community, customer dissatisfaction and economic costs for businesses and local governments.

Addressing these issues requires proactive efforts to promote collaboration and shared responsibility for achieving sustainable urban logistics goals. In Europe, the drive to influence local businesses to adopt sustainable choices for urban logistics is deeply rooted in the broader context of the EU’s commitment to addressing urbanisation challenges while mitigating environmental impacts. The EU's Transport Policy, the New EU Urban Mobility Framework and ambitious European Green Deal prioritise sustainable urban mobility and logistics, aiming to reduce greenhouse gas emissions, enhance air quality, and promote eco-friendly transport modes. With most of the European population residing in cities, urbanisation trends drive the need for efficient and sustainable urban logistics. Urban freight transport, especially last-mile delivery, presents significant challenges, prompting European cities to seek innovative solutions to reduce congestion, noise pollution, and emissions.

Various innovations are being analysed and tested to address urban logistics issues, such as transitioning from a linear economy model to a circular one. This circular model involves a detailed analysis and redesign of logistics flows, aiming for greater integration with personal transportation in more responsive and dynamic ways based on demand.

Simultaneously, public administrations are addressing urban logistics issues through planning instruments like Sustainable Urban Logistics Plans (SULPs). These plans primarily focus on externalities such as traffic, pollution, and noise that adversely affect the overall liveability of a city and the quality of life for residents and city users. Attempting to reduce the number of deliveries during peak hours and in congested city areas, local authorities have increased the number of stringent regulations on traffic and parking, imposing tolls and fees on commercial vehicles based on size and emissions.

Nevertheless, the task requires reconciling conflicting mobility needs in a dynamic environment: innovative planning tools are increasingly focused on the harmonised and real-time management of delivery and services, resulting in the elaboration of delivery and servicing plans.

On the operator side, the Logistics as a Service (LaaS) paradigm is emerging as an appropriate business model, offering on-demand logistics services, leveraging current technological advancements to connect demand with supply, i.e., customers with logistics service providers. Projects are expected to investigate aspects related to strong collaboration and shared responsibility among various stakeholders, leading to the adoption of framework agreements and governance models and bringing together freight transport operators, local authorities, local businesses, the community, environmental associations, and other relevant parties.

Projects should foster a shared awareness of issues and challenges related to freight transport and service management. They should also promote constructive solutions that reconcile the need for access to goods/services with local environmental and social needs by identifying and deploying effective governance measures enabled by increasingly interoperable and resilient technological systems in response to the sector's continuous changes.

Innovative governance models should push constructive dialogues that allow operators, real estate, and infrastructure owners to actively participate in local projects and identify, together with local authorities, rewards to operators that choose to pursue greater efficiency and sustainability in service delivery and purpose-oriented investments.

Focus should also be placed on developing tools to help strategic and tactical decisions concerning the design and deployment of new services and the setup of new, innovative support infrastructure. Adopting new distribution solutions, including integrating multiple modes and various types of business models and vehicles, should be explored. The many “sharing economy” concepts (vehicle sharing, parcel lockers, crowd shipping[53], information collection and knowledge creation) should also be an object of research. Multidisciplinary research and innovation should be pursued to optimise delivery and return processes in e-commerce, aiming to reach zero emissions. This multidisciplinary perspective is essential to connect stakeholder requirements with consumer behaviours and deploy in practice the developed interventions based on innovative technologies and infrastructure.

R&I activities should include:

- Demonstrating the use of zero-emission vehicles for urban freight, logistic services and local businesses’ transport needs (e.g. deliveries, stock resupplies, home-related services, waste removal);
- Harmonising freight-related data supporting the analysis of deliveries and services in urban and peri-urban areas;
- Using artificial intelligence (AI) and big data applications to validate the adoption and control of collaborative transport models;
- Developing standardised performance metrics and reporting systems for businesses' sustainability efforts in urban logistics and assessing the impact of transparency and accountability on decision making;
- Developing digital collaboration platforms that facilitate information sharing and coordination among local businesses engaged in sustainable logistics and evaluating the impact of such platforms on collaboration rates;

[53] Crowd shipping or crowdsourced delivery, also known as crowdsourced shipping, is the method used to deliver packages to customers by leveraging non-professional and local courier services.

- Studying the impact of awareness-building campaigns on businesses' and people's awareness and understanding of sustainable logistics practices and assessing which messaging and communication channels are most effective;
- Developing innovative models for providing incentives to local businesses that adopt sustainable logistics practices and researching the most effective types of incentives, such as tax incentives, subsidies, or preferential access to certain zones;
- Researching the impact of local and regional policies on businesses' sustainability choices in urban logistics and analysing the interplay between policy incentives and business decisions;
- Studying the role of local business networks and associations in fostering sustainable logistics practices and analysing the effectiveness of knowledge-sharing and collaborative initiatives within these networks;
- Carrying out cost-benefit analyses of sustainable logistics practices to provide local businesses with quantitative data on the economic advantages of adopting green strategies, including reduced operational costs and increased competitiveness;
- Researching the implications of local procurement policies that prioritise suppliers and logistics partners with sustainable practices and assessing the benefits and challenges faced by businesses in adhering to such policies;
- Developing frameworks for creating customised sustainability plans for businesses based on their specific logistics needs and capacities and evaluating the effectiveness of tailored plans in encouraging sustainable choices;
- Researching local businesses' adoption of eco-friendly logistics technologies, such as electric vehicles or route optimisation software and identifying factors that facilitate or hinder technology adoption;
- Conducting behavioural research to understand the motivations and barriers that influence businesses' decisions regarding sustainable urban logistics and analysing the psychology of decision-making in logistics practices;
- Exploring the impact of micromobility, micro hubs and mobility hubs in supporting last-mile delivery and other new service models for urban delivery.

Results are expected to contribute to the following outcomes:

- Standardisation of freight-related data, identifying and assessing consistent indicators and solid methodological approaches for collection and analysis of delivery and servicing dynamics in urban areas;
- Improved capacity in local authorities to adopt collaborative servicing and delivery planning by deconflicting diverging interests of mobility users and supporting the co-creation of innovative ecosystems based on fair and balanced governance models;
- Demonstration and assessment of effective measures significantly reducing negative impacts on transport, road safety and the environment derived from the adoption of delivery and servicing plans and related dynamic and adaptive measures;
- Municipalities and local governments working with local businesses to create a more sustainable urban logistics ecosystem, benefiting the environment, reducing congestion, and improving the overall quality of life in cities;
- Solutions for people and local businesses to make more sustainable choices for urban logistics, thereby creating climate-neutral cities;
- Alignment of local policies with local businesses' needs to foster local and regional economic growth.

Urban freight and logistics are considered a priority topic (projects concluded by 2030), requiring the development of a full call topic.

MILESTONES FOR SERVICE-RELATED SOLUTIONS

Services related solutions	Research and innovation topics	Type of action	Milestone
New mobility services	Developing innovative financing models for NMS outside of dense urban areas to allow for car-independent lifestyles also in peri-urban areas (e.g. multi-purpose use of on-demand vehicles for different mobility & logistics purposes)	IA	2030
	Evaluating methods to assess the impact of NMS (e.g. modal shift, reduction of car ownership, creation of intermodal trip chains, etc.), including designing simulation “models” to evaluate the global performance of these services (in a multi-criteria perspective) at a system level and to analyse the evolution of demand and technology adoption	RIA	2030
Next generation Mobility as a Service	Exploring different governance models for a public policy-driven MaaS, understanding the capacity of local and regional authorities, with data-sharing protocols between public and private entities and among private entities, and the links to cities broader climate neutrality and social goals	RIA	2040
	Investigating, developing and assessing different MaaS schemes and services benefits and impacts to a diversity of users, considering affordability, physical accessibility, different usage needs and coverage, and other stakeholders	IA	2040
Urban freight and logistics	Harmonising freight data, AI and big data for transport models, standardised sustainability metrics, and looking at the impact of transparency and accountability on decision making.	IA	2030
	Demonstrating the use of zero-emission vehicles for urban freight, logistic services, and local businesses' transport needs, and researching the implications of local procurement policies prioritising suppliers with sustainable practices.	RIA	2030
	Developing digital collaboration platforms for local businesses in sustainable logistics and evaluating their impact on collaboration rates and the effect of awareness campaigns on sustainable logistics practices, with behavioural research to understand what influence businesses' decisions regarding sustainable urban logistics, and analysing the psychology of decision making in logistics practices	IA	2030

Table 4 Service-related solutions – milestones

5C. Management-related solutions

5.9 Demand management

Urban Vehicle Access Regulations (UVARs)

UVARs aim to regulate motor vehicle access to urban areas, using regulations, physical interventions, and pricing measures. UVARs contribute to managing urban mobility challenges, environmental sustainability, and quality of life. The EU aims to reduce greenhouse gas emissions by at least 55% by 2030, prompting measures that encourage emission-free urban transport systems. Sustainable Urban Mobility Plans (SUMPs) play a vital role in integrating UVARs into broader urban mobility strategies. UVARs should be accompanied by impact assessments, stakeholder consultations, and comprehensive communication strategies.

Given the broad deployment in the EU, the EC's Expert Groups on Urban Mobility, in a recent paper, invite the EC to maintain UVARs as a key topic in urban mobility initiatives and research and innovation: Horizon Europe can provide the framework for continued research on UVARs in the context of climate neutral cities, scaled electromobility, new sensing and monitoring technologies, and advanced traffic management. The European regional differences, city characteristics, and specificities should be taken into account when addressing UVARs in these initiatives.

One of the main challenges in urban environments is the ability to reach road users at the right time, to inform, warn and, to a certain extent, restrict their behaviours to optimise land use, decrease congestion, improve health and safety, and promote cleaner vehicles and a just transport system. This will require an insight-driven system using promising technologies and solutions based on approaches such as IoT, ITS, C-ITS, AI, digital twins, and strong multi-stakeholder collaborations.

Location-based services, like geofencing, have gained immense popularity in marketing and advertising and can be effectively used for demand management-related applications. Geofencing involves creating a virtual boundary around a specific geographic location to monitor, inform, and control the traffic of mobile objects or vehicles entering, exiting, or located within the geofenced area. This can be achieved through electronic communication technologies or pre-defined geofences embedded into mobile objects/vehicles. Geofencing is an adaptable and efficient tool that finds extensive use in urban areas for various purposes.

Integration and harmonisation of geofencing-based services into existing systems can provide cities with additional tools to manage demand, with the potential to target and serve all transport modes, including active transport modes, freight transport, micro-mobility, PT and drones. Examples of applications are:

- Data platforms with geofencing capabilities that enhance communications between authorities, service providers and road users and provide valuable and up-to-date insights regarding the utilisation of space;
- Dynamic space management to optimise the use of kerbside, road, parking, and other confined areas;
- Enabling of distance-based pricing models in defined areas, such as distance-based road pricing;
- Dynamic priority-driven demand management activated by triggering factors e.g., special events, weather, traffic conditions etc., to promote just and efficient transport (e.g., by giving traffic light priority to active travellers in harsh weather conditions);
- Static, or dynamic speed limit recommendations, warnings and/or restrictions to ensure speed compliance;
- Monitoring and ensuring compliance of vehicles entering and exiting environmental zones, or other defined zones in the urban environment.

Parking:

Specific attention should be given to the following aspects of parking in R&I:

1. Integration in overall sustainable mobility planning: Research could focus on developing frameworks and guidelines for integrating parking strategies into Sustainable Urban Mobility Plans (SUMPs). This includes assessing the impact of parking policies on overall urban mobility goals, such as reducing congestion and emissions. Case studies and comparative analyses in different cities could provide insights into effective strategies for integrating parking solutions within broader sustainable mobility frameworks.
2. Integration with electric charging infrastructure and energy systems: Given the shift towards electric mobility, research could focus on scaled deployment of charging infrastructure in parking infrastructures. Topics could include optimising the placement and capacity of charging stations within parking facilities, evaluating the impact on grid stability and energy demand management, assessing the economic feasibility of integrating renewable energy sources with parking facilities, and integrated business models for parking/charging.
3. Building standards for parking facilities: There is a need for research on developing sustainable parking standards for buildings and design guidelines for parking facilities for different modes of transport such as cars, micromobility, LEVs and cycles. Topics could include exploring green building certifications specific to parking structures, evaluating the environmental footprint of different construction materials, and integrating sustainable design features such as green roofs, rainwater harvesting, and energy-efficient lighting and ventilation systems. Design in function of automated valet parking and next generation CCAM could be envisaged.
4. Digital technologies to manage and enforce parking: Research could focus on the application of digital technologies for efficient parking management and enforcement. Topics could include the use of IoT (Internet of Things) sensors for real-time parking availability monitoring, the development of smart parking apps for navigation and payment

systems, leveraging big data analytics to optimise parking operations and improve user experience, as well as the integration with Urban ITS.

5. Integration with access management strategies: Investigating how parking strategies can be integrated with access management systems to improve urban mobility. Research could explore the coordination between parking policies, public transport networks, and pedestrian/cyclist access routes. Topics may include dynamic pricing mechanisms to manage demand, integrating parking policies with congestion charging schemes, and evaluating the impact on accessibility and equity.
6. Dynamic and flexible parking solutions: Research could focus on developing dynamic and flexible parking solutions to adapt to changing urban needs. Topics could include exploring shared parking concepts, flexible zoning regulations to accommodate mixed-use developments, and pilot projects to test innovative parking management strategies such as demand-responsive pricing and adaptive reuse of parking spaces for alternative uses during off-peak hours.

5.10 Multimodal network management

Multimodal network management is based on the optimal use of the available (limited) capacity resources of the mobility network and infrastructure. Interactive road traffic management, mobility and network management aim to ensure efficient and safe movement of all users, including traffic flows of vehicles, and minimise the inevitable adverse consequences of the traffic process in urban settings (ecological, health-related, crashes, etc.).

In earlier EU R&D programmes, much of the focus was on trans-European transportation. While this directly benefitted the interlinkage of the EU Member States and has significantly impacted the availability of data and services on highways, a significant portion of these trips start or end in an urban environment.

The current context contains two paradigms: mobility management and network management. The first is related to the needs of persons and logistics and tailors offerings to users to assist in choosing an optimal trip; the second relates to the management of the transportation networks used and focuses on the safest and most efficient execution of these trips with the least impact on the environment. While these paradigms depart from different aspects, they are inherently linked by the transport modes, data and services used for these trips. While mobility is often multi-modal, management is historically single-network oriented.

Mobility network management (MNM) is, by definition, multimodal mobility management - the concept that promotes sustainable transport and manages the demand for car use by changing travellers' attitudes and behaviour. Therefore, integrated urban traffic management and mobility information systems can contribute to optimising transport flows through cities, metropolitan areas and rural regions. The transition towards an advanced multimodal transport system requires all road users to be better coordinated and mobility organised to optimise the entire transport network. This involves using devices for detecting actual traffic conditions, information sharing, vehicle tracking, connectivity and communication, optimisation processes and the distribution of control actions via end-user devices.

The MNM system aims to achieve sustainable multimodal mobility in the city by balancing capacity loads on different modes of mobility. Encouraging off-peak travel and alternative routes through intelligent applications and user information services can help maintain this balance. However, without a Common Operational Picture (COP) and coordination on transport modes, bottlenecks will constantly occur, posing a risk to user safety.

Impact-driven solutions upon which decisions on the provision of policies and priorities can be made need to take the potential benefits for different players, including private service providers and users, into account.

All related facilities, including mobility hubs, must be managed under a central mobility management centre to achieve the optimal capacity of a city's mobility network. To optimise traffic flows, this centre must integrate and oversee vehicle and public transport traffic management, trains, trams, metro, and ferries. The MNM authority will be responsible for orchestrating traffic distribution within the mobility modes, leaving no room for demand-driven management.

Mobility network management operates under the guiding principles of traffic management (TM) 2.0[54], which include co-opetition, trust, and dialogue. As MNM involves multiple stakeholders beyond just road traffic, it is necessary to fully map out all mobility stakeholders within the network and identify the different types of agreements and cooperation among them. An integrated mobility network system manages transport modes holistically in alignment with social and environmental targets set by public authority. A good understanding between city authorities and mobility operators is critical in this MNM approach.

To truly offer the best mobility advice, information from all transport modes and service providers is needed, spanning the entire trip. This involves choices balancing the potential use of multiple modes, dependent on the preferences of the person travelling or the shipper of goods and the availability of the networks for the entire trip. Enabling such a choice involves the data from all modes, including their estimated availability and travel time during the trip. A holistic information loop between the vehicle, the service providers, the infrastructure, and the traffic management centres (as per the TM 2.0 concept on interactive traffic management) is needed to enable traffic information service providers or traffic management centres (depending on who assumes the role of alignment and coordination) to inform and guide the road network users to their destination, while at the same time optimising the network throughput responding to the prevailing traffic conditions. To truly offer the best network management, a complete overview of the current and future capacity of the (multimodal) networks is critical, with the visibility and control of these networks being assured by Digital Twins technology. This will allow network managers to influence how mobility flows through the networks. This involves multimodal network management, incorporating foreseen trips and (faster than) real-time prediction models. To achieve optimal safety and efficiency with the least environmental impact, the mobility demand and transportation supply must be harmonised: integrated urban mobility and network management.

Following this approach, integrated mobility schemes should be based on the following 3 requirements:

[54] www.tm20.org

1. Communication of the traffic management plans and policies agreed by the public authorities to public and private traffic and mobility stakeholders (including MaaS providers and operators);
2. Making the mobility network policy and targets of the city digitally available (and in a uniform format);
3. Establishing regular dialogue between public authorities, the navigation service providers and MaaS providers and operators so that city recommendations on the road network can be taken into account when routing services are provided to users.

R&I activities should include:

- Developing governance and organisational models for cooperation between the road traffic actors involved, defining, on the one hand, the TM real-time information that needs to be made available and accessible to vehicles and to facilitate concise and coherent information loops that enable users (drivers) to safely and efficiently reach their destination;
- Implementing standardised methods for public authorities to share road maintenance information/ locations with traffic management coordinators so this can be integrated into their re-routing / decision making processes;
- Developing feedback loop schemes so that information (feedback loop) from the vehicles to the mobility network management system (controlled by either public or subcontracted private authorities) can provide maximum benefits at a network level, as the Common Operational Picture (COP) is based on these information loops;
- Developing service offerings to persons and goods linking with multimodal network management;
- Demonstrating multi-modal advice and guidance;
- Demonstrating means of monetising the societal benefit of safety, efficiency, and reduction of environmental impact to allow for payment of services.

Results are expected to contribute to the following outcomes:

- Taxonomy of networks, transportation modes and ecosystem;
- Business models to convert societal benefits into viable financial services;
- Services to support persons or goods throughout the entire trip, where the digital service is linked to physical transportation and an underlying network;
- Transferability of services (for example, a mobility service from one city or country should be usable in another).

5.11 Integrating urban mobility within overall European transport chains

Urban nodes, which are key hubs in the urban freight and supply chain, are often plagued by dense traffic and congestion, leading to connectivity issues and bottlenecks. To address this, existing infrastructure such as railway stations, airports, ports, and multimodal freight terminals in and around major cities should be well connected within the cities and functional urban areas. Additionally, cities need to be well connected to other cities and transport hubs, both regionally and internationally. Therefore, it's important to have reliable last-mile connectivity not just within urban nodes but also with the rest of the intraregional and international transportation networks.

In the transportation industry, the Physical Internet (PI) refers to the combination of digital transportation networks that are being created to replace traditional transportation networks. Logistics innovation experts have used the PI concept to tackle challenges faced by urban logistics, such as congestion, pollution, limited space, and climate change. Due to the rise of e-commerce and related home delivery services, cities have been compelled to take action to reduce carbon emissions from freight transport in urban areas. Therefore, logistics innovation experts have developed solutions using the PI concept to optimise the use of assets, enhance efficiency, reduce traffic flow, and mitigate negative impacts on the environment and society.

Support for zero-emission logistics is one of the major trends boosting the PI market's expansion. As awareness of climate change and environmental sustainability grows, there is a tremendous effort to reduce carbon emissions in the transportation and logistics sector. The PI has the potential to create a more cost-effective and environmentally friendly logistics system by streamlining the movement of freight, lowering operating costs, and improving the working environment for delivery drivers in general.

Digital twins are virtual replicas of physical assets, processes, systems, or environments that mimic the appearance and behaviour of their real-world counterparts. Digital twins have become a popular approach in urban modelling, offering real-time views of city assets and simulations to test future projects, helping policymakers make informed decisions about plans and projects and ensuring they meet both short-term and long-term goals. However, creating these tools for urban logistics requires ongoing collaboration with various stakeholders to generate value throughout the city. This not only enables digital twins to serve as a visualisation tool but also facilitates the co-creation of knowledge among stakeholders. This is especially important in the context of logistics innovation, where the involvement of multiple stakeholders and objectives can result in a lack of sustainable business models and innovation failure.

In-depth research is possible for future planning, infrastructure development, and freight operations thanks to reliable and ample data. Governments and city planners may be able to provide strategic data to guide network design, investment decisions, and freight policy more efficiently and affordably than they could in the past with conventional large-scale sample surveys as a result of the ever-growing digitisation of freight transport.

The introduction of new technologies in the supply chain and logistics sectors presents opportunities for freight service providers to enhance delivery processes and partner interoperability.

R&I activities should include:

Urban nodes

- Focussing on implementing multimodal hubs for passenger and freight supporting zero-emission mobility and transport, at the inner city and metropolitan scales;
- Creating guidance to define ideal locations for freight terminals and to lay the ground for more efficient and sustainable supply chains (both towards urban deliveries and long-haul transport);
- Addressing policy incoherence at horizontal and vertical levels across Member States;

Physical Internet

- Focussing on data-sharing frameworks that allow the use of data safely and collaboratively between the private and public sectors;
- Developing open systems and protocols driving flow consolidation;

- Developing and applying new collaboration models addressing different flows, B2B & B2C hybridisation, and multi-industry reverse flows;
- Developing digital twins scenarios for urban freight-related activities for a better understanding of current and future flows with defined frameworks.

Results are expected to contribute to the following outcomes:

Urban Nodes

- Better understanding in urban nodes of the future work and closer interaction with TEN-T stakeholders (EU coordinators of TEN-T corridors);
- New policies that consider requirements for urban nodes to develop multimodal passenger and freight terminals (different time horizons in 2030 and 2040);
- Cooperation among the private sector, freight terminal operators, clusters of logistic companies, etc.

Physical Internet

- Roadmaps toward the implementation and exploitation of hyperconnected city logistics with new business models for the various infrastructure, service providers, and users;
- Sets of enabling city policies and regulations with a public governance perspective;

This topic is considered a longer-term R&I issue.

MILESTONES FOR MANAGEMENT-RELATED SOLUTIONS

Management related solutions	Research and innovation topics	Type of action	Milestone
Demand management	Parking: Integration in overall sustainable mobility planning: Research could focus on developing frameworks and guidelines for integrating parking strategies into Sustainable Urban Mobility Plans. This includes assessing the impact of parking policies on overall urban mobility goals, such as reducing congestion and emissions. Case studies and comparative analyses across different cities could provide insights into effective strategies for integrating parking solutions within broader sustainable mobility frameworks		
	Parking: Integration with electric charging infrastructure and energy systems: Given the shift towards electric mobility, research could focus on scaled deployment of charging infrastructure in parking infrastructures. Topics could include optimising the placement and capacity of charging stations within parking facilities, evaluating the impact on grid stability and energy demand management, assessing the economic feasibility of integrating renewable energy sources with parking		

Management related solutions	Research and innovation topics	Type of action	Milestone
	facilities, and integrated business models for parking/charging are also to be studied		
	Parking: Building standards for parking facilities: There is a need for research on developing sustainable parking standards for buildings and design guidelines for parking facilities. Topics could include exploring green building certifications specific to parking structures, evaluating the environmental footprint of different construction materials, and integrating sustainable design features such as green roofs, rainwater harvesting, and energy-efficient lighting and ventilation systems. Design in function of automated valet parking and next generation CCAM could be envisaged.		
	Parking: Digital technologies to manage and enforce parking: Research could focus on the application of digital technologies for efficient parking management and enforcement. Topics could include the use of IoT sensors for real-time parking availability monitoring, development of smart parking apps for navigation and payment systems, leveraging big data analytics to optimise parking operations and improve user experience, as well as integration with urban ITS		
	Parking: Integration with access management strategies: Investigating how parking strategies can be integrated with access management systems to improve urban mobility. Research could explore the coordination between parking policies, public transport networks, and pedestrian/cyclist access routes. Topics may include dynamic pricing mechanisms to manage demand, integrating parking policies with congestion charging schemes, and evaluating the impact on accessibility and equity		
	Parking: Dynamic and flexible parking solutions: Research could focus on developing dynamic and flexible parking solutions to adapt to changing urban needs. Topics could include exploring shared parking concepts, flexible zoning regulations to accommodate mixed-use developments, and pilot projects to test innovative parking management strategies such as demand-responsive pricing and adaptive reuse of parking spaces for alternative uses during off-peak hours		

Management related solutions	Research and innovation topics	Type of action	Milestone
Multimodal network Management	Developing governance and organisational models for cooperation between the road traffic actors involved, defining traffic management real-time information availability and accessibility, and the links between digital service and physical transportation, allowing for safe and efficient mobility systems	IA	2030
Integrating urban mobility within overall European transport chains	Developing guidance on ideal locations for implementation of multimodal hubs for passenger and freight supporting zero-emission mobility and transport at inner city and metropolitan scales in Urban Nodes, laying the ground for more efficient and sustainable supply chains (urban deliveries and long-haul transport), also addressing policy incoherence at horizontal and vertical levels across Member States	RIA	2040
	Developing and applying new collaboration models addressing different flows, B2B & B2C hybridisation, and multi-industry reverse flows for the Physical Internet, with open systems and protocols for driving flow consolidation	RIA	2030-2035

Table 5 Management-related solutions – milestones

5D. Integrated solutions

5.12 Active travel modes

Actively moving around in the city brings many benefits at an individual level and in the public realm, contributing to reducing transport emissions and increasing health and quality of life. Active modes, namely walking and wheeling[55], (e-)cycling and possibly other mobility modes that may use direct physical effort, are the most democratic and sustainable modes, where emissions are zero or close to zero. Active modes further support other ecological, social and economic benefits such as less space demand, negligible wear and tear to roads, cost efficiency, speed (at least in most urban contexts), lower costs, public health, social interaction, and flexibility. Very importantly, active modes are inherently more resilient than forms of transport that rely more heavily on systems, machines, data exchange, labour forces or energy sources. Moreover, as part of multimodal systems, active modes can increase the reach and efficiency of PT and sharing schemes, covering the first and last mile of journeys in urban or peri-urban/rural journeys.

[55] Using the terms walking and wheeling together brings representation to a broader group of people since it includes pedestrians walking, using wheelchairs and other types of aids and personal assistive devices, and people identify with them differently. Both terms describe moving at a pedestrian's pace, unaided or aided. https://wheelsforwellbeing.org.uk/walking-wheeling-and-cycling-definitions/

Active travel can bring independence, a greater sense of belonging and an understanding of our surrounding environment (built or natural). Walking and wheeling, and cycling are human-scale modes of transport that bring people into contact with one another and promote social cohesion at the neighbourhood level. Active modes, especially walking and wheeling, can be the one, first and most convenient transport choice for many people, for example, older people, children/teenagers, and other people who choose not to or cannot engage with PT, driving or other transport.

Active travel also contributes to better health and wellbeing outcomes. More needs to be done to align mobility and health policies and take advantage of the co-benefits that active travel brings for people's health by systematically assessing and valuing how active travel contributes to, for example, daily physical activity and better mental health. The World Health Organisation recognises active travel as a type of physical activity that can contribute to health targets, reduce sedentarism and health risks (e.g., reduced risk of diabetes, depression, obesity, and cardiovascular diseases) and recommends increased cross-sectoral and cross-level policies and importantly, budgets. Research and policies initiated by mobility and transportation should look beyond technology and infrastructure, taking these societal benefits into account to prioritise mobility solutions that contribute to wider health and social, as well as economic and environmental goals.

Given their wide-ranging positive impacts, active modes should be prioritised on the path to decarbonisation and should guide the organisation of cities and transport systems. As much as possible, active travel should be seen as the first and most logical choice to prioritise. This means making it safe, comfortable, accessible and inviting to everyone, regardless of age, physical ability, income, gender, time of day, etc. For people to walk and wheel, and cycle, they should be able to do so without fear of crashes, conflicts and social insecurities and without obstacles or barriers.

Walking, wheeling, and cycling require infrastructure with different particularities, such as providing shade, greenery, seating, appropriate lighting, basic amenities (e.g., public toilets), wayfinding, tactile pavement, street signage (e.g., horizontal and vertical signs, traffic lights), safe crossings and intersections, dropped curbs, appropriate dimensions, pleasant routes, segregated paths, appropriate inclinations, secure cycle parking facilities, space for diverse users, and others. Infrastructure for active travel must be built at a human scale, create connected routes and networks, and consider the different paces of flow and behaviour.

Land use, density, diversity, and quality of the public space are key in enabling improved active travel modes. The 15-minute city model and other people-centred urban planning and design approaches support walking, wheeling and cycling. Nevertheless, in less dense areas, facilitating multimodality and intermodality will also support active modes, providing a wider range of options beyond just the private car. Exploring how urban planning, housing and employment distribution, densification and new neighbourhood developments can support active travel and vice versa will create new tangible possibilities for climate-neutral cities.

Active mobility is valuable for entire journeys in and of itself and is crucially important as a first- and last-mile solution in combination with PT. Integrating active mobility with PT and new mobility services (e.g., shared mobility) is a key strategy to achieve the full potential of a sustainable and just urban mobility system.

In combination with active mobility, PT systems need to be further expanded and enhanced to make mobility more affordable, accessible, clean, convenient, less congested and safe. While walking and

wheeling have been the traditional means of access to PT, integrating (e-)cycles and other micromobility modes extends the catchment area. This requires good infrastructure for walking, wheeling and cycling to and at PT nodes and mobility hubs. Different and improved options for cycle parking facilities, allocating space to transport these in trains and buses at reasonable or no cost, and considerations for sharing schemes will support the combination of PT and cycling, which might be particularly relevant for serving peri-urban and rural areas.

Pedal-assisted e-cycles (pedelecs) bring new dimensions to active travel and multimodality since they preserve the benefits of active travel while increasing range and enabling cycling for a more diverse group of users (e.g., older adults and people with physical constraints). Within multimodality and sharing schemes, e-cycles could be a game changer for trips that currently are too long, hilly or tiring to be made using standard cycles. For some, electric support and different adapted cycles (e.g. tricycles, tandems, hand cycles), can also provide the support needed to enable them to cycle, unlocking the benefits and potential of cycling for more people. Moreover, when considering suburban areas and unsustainable incoming commuter traffic, e-cycles combined with cycle highways, have great potential as a more sustainable and convenient option for people.

Active modes have already started to support a more sustainable last-mile delivery of goods, especially in dense city centres. Cargo (e-)cycle enable sustainable urban delivery, bringing benefits to workers, businesses and residents while contributing to improved use of public space and kerbside. This can support the local economy and open new possibilities for the workforce and working conditions. Cargo (e-)cycles can also be a more sustainable option for individuals, facilitating the transport of children, groceries and household items.

The increased support for developing different types of cycles, in terms of local European production, standards and regulations, is essential in the equitable uptake of cycling. Accordingly, policies and schemes for electric, cargo and adapted cycles must address affordability, accessibility, and safety. Moreover, cycling infrastructure and streets must also allocate sufficient space to accommodate a diversity of cycle types to minimise conflicts and risks for cyclists, pedestrians and other users of the public space.

With an increase of different micromobility vehicles, particularly those that are not active (e.g. e-scooters and monowheels) and have higher speeds (e.g. e-cycles), it is essential to understand and accommodate their different needs and users. This is specifically relevant for walking and wheeling, which can be marginalised in strategies and policies, hindering their essential presence in the urban space. To advance sustainable mobility, it is thus relevant to bring slow-paced active modes and faster paced micromobility into joint discussions, paying particular attention to their interactions and potential within multimodality. It is crucial for cities to gain a clear sense of how collaborative thinking and discussions can benefit these modes while also identifying what the conflicts and trade-offs are. At the same time, when it comes to allocating and designing urban space and mobility management, walking and wheeling must not be played off against other types of micromobility but instead be in harmonised cooperation.

Sustainable mobility includes both ecological and social aspects. Just mobility deals with measures and policies, and research for active mobilities must be inclusive to ensure that all social groups can participate and benefit. For example, in countries that traditionally have a strong cycling culture, with high-quality infrastructure and safe cycling overall, the percentage of women cycling is higher (e.g., Netherlands and Denmark). This is linked to various reasons, for example, less stigma towards women cycling, overall sense of safety, and typical trip patterns for women (trip chaining including multiple short trips rather than longer work commuting trips, e.g. mobility of care), which makes cycling an optimal choice of transport.

However, this is not the case in all contexts, where the choice to cycle can be hampered for some groups of society that do not feel safe or welcomed in doing so.

To reach equitable mobility systems, it is essential to consider and include all social groups in different contexts. This is the case for active travel more broadly, and justice considerations on inclusive data collection and analysis to ensure equitable policymaking are even more urgent in the light of AI and training sets. To ensure equitable growth in active modes, policies must consider who currently walks, wheels or cycles and how to make it accessible and attractive to those who currently do not. Active mobility data and policy should consider age, gender, ethnicity, disabilities, income and social groups.

A transition towards sustainable mobility that emphasises the role of active mobility should include measures such as reduced speeds, priority traffic lights for active modes, traffic calming, and shared space models. Parking measures are also central in such a transition, with appropriate and secure cycle parking (at transport hubs, stations and public/private buildings) and reducing on-street car parking. This transition must also include data collection, mobility management and ITS solutions for active modes that receive at least equal development and funding as other transport solutions.

R&I activities should include:

- Understanding how urban planning and housing availability support or undermine active mobilities (e.g., compact urban planning of the 15-minute city and cycle-based and public transport-based suburbanisation), through living labs, co-creation and public involvement;
- Examining how active mobilities can be well integrated with PT and other modes, strengthening multimodality and available mobility options (e.g., in terms of safety, costs, infrastructure, seamless integration, and multimodal services);
- Investigating improved planning and design of active travel infrastructure, considering different approaches to flexible and dynamic street space reallocation, public space quality, shared spaces, kerbside management, and connected routes and networks;
- Exploring which mobility management policies best serve to promote active modes (e.g., flow, speed, traffic lights, parking facilities, land-use prioritisation) and the development of innovations (technology and governance) that will achieve this;
- Developing innovations and best practices (technology, urban design and governance) to increase the safety of pedestrians and cyclists, both as single users and in interactions with other modes, particularly considering micromobility, to update infrastructure guidelines, road space priorities, as well as national, regional, and local transport safety policies;
- Evaluating the benefits of active mobility for wider societal cohesion and the extent to which they play a role in countering negative social and political trends such as increasing polarisation and social isolation and how social movements help active mobility advocacy and research (e.g., building coalitions, mobilising user-oriented knowledge;
- Examining how the cultural status of active mobility plays into policies (e.g., cycling is seen as an aspirational lifestyle, leisure, and utility for people experiencing poverty) and the messages that would best work to attract different cultural groups to cycling;
- Research on local cycle ecosystems, considering industry, services, policies and end users, looking into their relevance, enhancement and distribution across Europe;
- Combining social sciences and technological research to examine choices, behaviours, and perceptions, but also to include the needs of a variety of people, increasing representation and equity in active travel.

Results are expected to contribute to the following outcomes:

- Improved public space, with safer, more accessible and comfortable infrastructure for active modes, with a rebalance in the prioritisation and distribution of public spaces;
- Active travel as a viable, safe, affordable, convenient and inviting transport choice;
- Reduce the experienced and perceived "vulnerability" of pedestrians and cyclists as users of streets and public spaces, with fewer to no fatal crashes;
- Improved multimodal systems and services that prioritise active modes, enhancing first and last-mile options and efficiency, for example, by providing secure cycle storage, integrated payment for PT and shared cycles/scooters, etc.;
- Strengthened EU and local cycle industry that offer diverse, affordable types of (e-)cycles – including for children – and different supports and incentives facilitating their acquisition;
- Increased availability, presence and use of different types of (e-)cycles and (e-)cargo cycles by end users and urban logistics providers;
- New technologies and ICT tailored for active modes and their prioritisation, with innovations and new solutions that will increase inclusivity;
- Standards and regulations for active modes data to support evaluation and indicators;
- Improved organisational and professional capacity in regional and local authorities to implement and deliver high-quality infrastructure and public space;
- New policies and frameworks (including cost-benefit) that holistically consider transport, health, urban planning, social and environmental sectors and that internalise the costs of all modes of transport;
- Roadmaps for planning and implementation of active modes that can be applied to different contexts, allowing for the prioritisation of active modes within transport systems.

Active travel modes are considered a priority topic (projects concluded by 2030).

5.13 Light electric vehicles – new vehicle concepts for urban use

The following content is extracted from the ERTRAC Urban Mobility Working Group (UMWG) paper *LEVs in Urban Mobility Research and Innovation Priorities.*

LEVs are booming in Europe, with a diverse range of options appealing to various target groups. Shared micromobility is on the rise, making it an essential part of the local mobility ecosystem, with e-scooters, but also electric cycles, electric cargo cycles, e-mopeds and light three- and four-wheeled vehicles. LEVs are also gaining importance in sustainable logistics. Although there are challenges, the growth of LEVs presents promising new perspectives and research opportunities. This section outlines the topics, questions, and context of LEVs in urban mobility and highlights research and innovation priorities identified in the paper.

The current status of LEVs in regulatory frameworks clearly shows the need for a consistent and aligned definition. Uniform classifications and terminology would facilitate futureproofing the drafting of legislation and policy, as well as serve to align terminology used on the EU level, nationally and locally. Research which supports an examination of present terminology, simplification of classifications and related

guidelines would benefit this cause. However, a substantial amount of research should be carried out before lifting existing consumer safety regulations in order to avoid potentially unsafe results.

The infrastructure must be adapted to ensure safer accommodation of these vehicles. It is relevant to consider aspects of the use and design of public and private space, infrastructure safety, mobility hubs and secure parking facilities, and charging infrastructure / swappable battery technology.

Traffic codes and rules should be reviewed from a holistic perspective of the growing diversification of vehicles on the road. To support the usage of smaller LEVs, research should be conducted on effectively implementing incremental changes and re-allocations of space that can begin to counteract decades of car-centric planning towards a better balance. Research is also recommended on the dynamic management of space (function, time of day usage, space allocated to parking vs. other uses, etc.) and the placement and future planning of supporting infrastructure (charging, signage, etc.), which does not obstruct or subtract from the space allocated to LEVs and active mobility.

Research is lacking regarding the interaction between >25 km/h LEVs (e.g., speed pedelecs) and other <25 km/h vehicles (e.g., cycles) in dedicated lanes. Consequently, investment in infrastructure safety, with a particular emphasis on road space allocation, and the review of traffic codes emerge as critical determinants in promoting the use of light electric vehicles. This underscores the need for further research and policy focus in those areas.

Mobility hubs serve to support journeys using a combination of modes. In order to support sustainable first/last/ as well as mid-journey solutions, parking should be secure, charging should be an option, transfers should be convenient, and barriers should be minimised, such as parking costs and rental of LEVs through a common platform which allows a simplified approach to pick up and return to various locations.

The characteristics of LEVs create specific parking concerns. The cost of the vehicles and the fragility of the technology raise concerns about open-air and unprotected parking and increase the need for secure parking facilities. Further research is needed in integrating charging into secure parking facilities.

Research is still needed in relation to optimising LEV parking security, as smaller electric vehicles represent significant personal investment supporting a shift to sustainable mobility and remain the target of thieves despite various security measures which are often in place.

Further research is needed in leveraging data to support MaaS solutions, space management, and security in multimodal hubs to enhance intermodality. This would support the integration of LEVs as a convenient and viable part of longer journeys.

Battery-swapping infrastructure could be more energy-efficient and cost-effective to implement than traditional charging stations in certain settings, particularly in urban areas where space is at a premium. However, to fully realise this potential, it is crucial for the EU to establish a harmonised standard for swappable batteries, ensuring interoperability across different manufacturers and regions. This will not only foster innovation and competition but also facilitate the creation of a robust, pan-European battery swapping network. The value of swappable battery technology is a topic for further study.

Safety is central in the deployment of LEVs. Vehicles need to be designed to be safer, the safety of equipment and battery, behaviour change and regulatory measures which can support safety.

The existing legal framework and safety standards should be assessed for the production and testing of LEV vehicles, related batteries, and electronics to enhance consumer safety.

Regulations, standards, and tests should be scrutinised to find out whether they are optimised for electric vehicles. Even where standards exist for comparable products, there may be inconsistencies in the requirements within those standards. This may be due to a legacy issue or lack of liaison between different technical committees responsible for drafting and developing interrelated standards. Further research should be carried out to align safety standards, including legacy issues and consider future innovation on the radar in order to address and avoid such inconsistencies. This effort should involve the cooperation of key technical committees and related stakeholders in order to bring various areas of expertise to the table.

Technological systems in the field of active and passive safety, especially for larger LEVs such as microcars, must be further researched to assess potential improvements to occupant safety and the safety of other road users.

Speed pedelecs and e-scooters with seats are categorised as mopeds. Further research should focus on understanding how to improve technical legislation, road infrastructure and existing guidelines for these new vehicles.

LEVs with speeds equal to or below 25 km/h, the guidelines designed for cycles should be deemed applicable, given that most of the LEVs have a comparable or even lower kinetic energy. Data on crashes with these vehicles is either missing or (under)reported under different vehicle categories. Therefore, safety and potential safety issues are difficult to assess. Research focused on standardising the collection of this data as well as on assessing the impact on existing cycle lanes and at what point the increased usage requires expanded space to ensure user safety.

Focus is needed to address safety aspects, such as training to ensure familiarity with new types of vehicles, the need and required adaption of licensing training for LEVs, and the determination of the best space for various new modes. Safety risks exist for LEV users on the roads and potentially for slower users in the cycle lanes. Regardless, clearly designating and optimising these spaces would help reduce friction with other modes and reduce negative perceptions of LEVs.

LEVs are on the rise. This development requires extra attention to the (fire) safety of LEVs by manufacturers and further research on the development of innovative battery management systems, not only for passenger cars but also for LEVs.

Fire safety is a topic that has been mentioned several times during the SRIA update of the 2Zero Partnership, but the main topic of interest was related to the safety of charging in (underground) garages, and there has been no particular focus on fire safety of LEV and e-scooters yet.

A recommendation might be to push for R&I, as well as collaboration, between public authorities, OEMs and other stakeholders with Batteries Europe (the technology platform of batteries). They also have a safety task force which might have already identified some activities.

Research would be valuable regarding the determination of LEV user groups and the development of LEVs for specific target groups, e.g., older/younger people with disabilities.

How the future adoption of these vehicles and the resulting modal shift will look is largely unknown due to the lack of comprehensive data, including on reasons for users choosing to use (or not use) LEVs and what their alternative modes would be.

Inexperienced users of LEVs, for example, first-time users of shared e-scooters, are often not aware of the speed and the acceleration that these vehicles are capable of, putting these users at higher risk. Inadequate user behaviour increases the risk of single crashes and crashes with other street users.

There is also the risk of battery fires, as a puncture or an impact from a crash may result in the batteries igniting and lead to “thermal runaway” of the chemicals inside the battery. Thermal runaway cannot be stopped once it starts without specialist fire suppression and containment equipment. This has resulted in many injuries where people have tried to stop the fire using standard fire extinguishers.

Manufacturers, operators and public authorities need to raise awareness for proper user behaviour and inform/train users. These stakeholders should contribute to fire-safe behaviours of consumers with information about fire-safe use (maintenance, loading, storage).

Research is needed on assessing mitigating measures which may be necessary to address user aspects (competence, training, personal choices on e.g., wearing protective equipment), vehicle aspects (technical aspects, maximum speed, etc.), interaction in traffic with other road users/traffic participants, aspects in the environment/surroundings (infrastructure, road type use, road conditions, etc.), and impacts of various regulations and legislation on different levels (where these vehicles are allowed, shared/rented vs. private, etc.).

While there are numerous positive impacts of LEVs, the impacts of the sourcing and disposal of materials, especially in regard to the batteries – including end-of-life collection, recycling systems and the recovery/re-use of materials should be further researched. Research is needed to assess the systems in place and best practices. Research would also be beneficial in examining manufacturing, marketplace, consumer, operations (shared services), and municipal and national practices - to resolve the results of no plans in place and further explore best practices.

A significant environmental impact can only be achieved if LEVs are used in considerably higher numbers than today, replacing less sustainable vehicles. In all likelihood, communication measures and incentives (financial, regulatory, etc.) alone will not be sufficient to bring about such a change within the timeframe set by climate protection targets. Rather, a holistic approach is needed that addresses many fields and combines incentives with "push" measures aimed at discouraging the use of heavy vehicles. Research can provide valuable insights to support this challenging task, as acceptance of push measures is usually harder to achieve than pull measures. So, in addition to research on life cycle assessment, increasing lifetime performance and similar issues, research on environmental impacts must also focus on implementation issues.

Further research is needed on the effects of different sets of measures that include regulation of different areas and push and pull measures.

In view of the high urgency and relevance for the GHG emission reduction, reliance on incentives is probably insufficient. Further research is needed to investigate the possible effects of different sets of measures to support climate mitigation effectively, efficiently, reliably, and rapidly. Sets of measures could affect regulation, infrastructure, (external) costs and more. Push and pull measures for behavioural

changes need to be accompanied by safe, affordable and convenient transport options. Further research should be conducted on the situations, infrastructure, and factors which “allow” and “support” this shift to LEVs and sustainable transport - within homes, organisations, and by public authorities.

Further research needs to be carried out on LEV use cases beyond major city centres and in rural areas to establish viable business models for low-density areas and identify specific opportunities and constraints which may be tackled by push and pull measures, e.g., the use of the e-cycle for longer commuting distances, coupled with long-distance cycling infrastructure, so-called super cycle highways.

An example for successful implementation of LEVs as a means of transport is Japan. There, small Kei cars (smallest highway-legal passenger car category) are a popular mode of transport. Influenced by the high cost of car ownership and by space restrictions, they accounted for 28% of all vehicle registrations in 2021. 14% of all Kei cars are in high density areas with 4000 inhabitants per km^2, compared to 45% in low-density areas with 500 inhabitants per km^2. 80% of light car users in low-density areas use them for their daily needs, in comparison to 42% of users in high-density areas. Transferability to European suburban and rural areas needs to be further researched and studied.

Additionally, international LEV solutions, take-up and use should be further studied to explore the potential for transferability to European suburban and rural areas.

Research and innovation topics should include the following elements and considerations in order to explore and share best practices for a range of scenarios.

R&I activities should include:

- Understanding the social, ecological, and planning implications of scaled roll-outs;
- Understanding user acceptance factors and user requirements, including a gender perspective;
- Understanding and reducing obstacles to uptake;
- Investigating possible incentives - factors for maximising uptake;
- Collecting and analysing evidence of successes and failures, the reasons for them, necessary framework conditions, good practice and lessons learnt.

Results are expected to contribute to the following outcomes:

The way towards successful integration and adoption of LEVs can differ substantially among the various types of LEVs. Successful deployment and scaled market uptake can be compared with less successful cases, learning the framework conditions and processes needed for success, as well as approaches, use cases or unsuccessful business models. As most of this activity will be based on real-life experience, a methodology to understand and share successful cases, facilitate the exchange of best practices, and share lessons learned could be developed.

New vehicle concepts for urban use are considered a priority topic (projects concluded by 2030), requiring the development of a full call topic.

5.14 Advanced automation in an urban context

The ERTRAC Working Group “Connectivity and Automated Driving” recently updated information from the ERTRAC CCAM Roadmap published in 2022, specifically the update of Chapter 2 "Agenda 2030" on Innovation Use Cases. The following is an extract of this information.

The Agenda 2030 is crucial for the ERTRAC CCAM Roadmap, describing separate areas of innovation of CCAM products and services that differ in various characteristics, develop in different timeframes, and offer a wide variety of use cases. In total, they represent an operational agenda for research, standardisation, regulation and investments. The Agenda 2030 should be seen as a supplement to the SRIA of the CCAM Partnership, providing some more concrete opportunities for applications within this timeframe and enabling a better understanding of the feasibility of use cases for their application in large-scale demonstrations.

Within the framework conditions for large-scale demos, all use cases require infrastructure support and need to be evaluated based on societal needs and market adoption opportunities to prioritise large-scale demos. After a large-scale demo project, the goal is to support technical standardisation, develop type approval and road regulations, and establish operational aspects and cooperation models. The demo site should have improved sustainably and provide valuable insights for users and society, ideally leading to the commercial deployment of demonstrated services.

Domains for innovation

The Agenda 2030 is structured in five innovation domains, distinguished according to their traffic complexity, following their applications, complexity, technical maturity, market readiness, and societal needs. They are supported by a horizontal layer for connected and cooperative services.

The aim is to bring as many application areas, stakeholders and use cases together to enable the economy of scale and best use of synergetic effects for society, specifically addressing the affordability of mobility and transport and value generation to end users like citizens as well as mobility, transportation and logistics providers. The five domains are:

- **Parking** - including automated valet parking (AVP) with strong infrastructure support (AVP Type 2) and based mainly on vehicle technologies (AVP Type 1).
- **Confined areas** - Various use cases will be implemented in confined areas following specific requirements on environment, traffic and legal requirements. Early demonstration will further drive industrialisation, adding newly designed service functions with higher levels of automation.
- **Highways** - Operational Design Domain (ODD) extension for all vehicle types on the primary road network with infrastructure support to demonstrate robust and reliable automated driving interoperable across countries and brands.
- **Urban and peri-urban transport for people and goods** - This is the most important contributor to the societal objective of energy efficiency and liveability in urban areas, linked to peri-urban areas generating traffic due to commuting transport needs, and first and last mile. `
- **Rural and secondary road network** - The biggest challenge is combining high vehicle speed with full traffic complexity, with limited coverage of digital infrastructure (mobile network, HD maps, etc.)

– even in the long term. This is the most important contributor to the societal objectives of safety, inclusiveness and accessibility, including the accessibility of urban and peri-urban areas for the rural population.

These are supported by the layer of connected and cooperative services - Improving traffic and logistics/mobility services also without higher levels of automation, adding connectivity and digitalisation to existing services (including remote assistance and management). This is horizontal to all the application areas.

As identified by the CCAM Partnership's SRIA (2022)[56], which challenges the deployment of safe and sustainable CCAM solutions, it is important to highlight the need to achieve a common understanding among all relevant actors and the general public of the long-term implications, benefits and impacts of integrating CCAM solutions into the mobility system. "A proactive planning approach is required to effectively regulate how the introduction of Connected and Automated Vehicles (CAVs) should unfold, minimise the potential negative impacts and, more importantly, make the most of the opportunity to influence the paradigm shift into a more sustainable urban mobility vision" (Rupprecht Consult 2022).

To this end, it will be essential to "develop CCAM solutions and mobility services strengthening and complementing existing PT, which are attractive for service providers, operators and -users of automated and shared vehicles. In addition, business models and use cases for automated and shared vehicles need to be developed, as well as interoperability and integration with PT. (…) The intended services need to be well integrated with urban planning and urban economics, with appropriate governance models in order to ensure a high degree of acceptance among all stakeholders." (SRIA, 2022).

R&I activities should include:

- Assessment and evaluation of benefits and impacts of different CCAM use cases in integration with urban mobility systems
- Exploration of different ways CCAM solutions can complement PT and other mobility services, with seamless interoperability and integration, new business cases and regulations
- Development of case studies of CCAM solutions responding to different morphologies (urban, peri-urban rural) and mobility needs, both for people and goods, aiming to provide more sustainable options and services
- Examination of governance and policy schemes that enable cooperation and alignment of CCAM solutions with land use, urban planning, environmental and social objectives

Results are expected to contribute to the following outcomes:

- Innovative CCAM solutions that are well integrated and aligned with broader sustainable and social goals in cities and regions
- Urban mobility systems and CCAM solutions working in cooperation to provide a variety of services and options for different user needs

[56] CCAM SRIA 2021 - 2027

5.15 Integrated solutions: Coach and the city

Coach travel is an important element of collective mobility chains and mass transit systems in, around and between European cities. Long-haul and local coaches for tourism raise challenges and opportunities linked to transport infrastructure, sustainability, air quality, accessibility and inclusivity, space use, congestion and safety for coach passengers and residents living in tourism cities.

Collaborative efforts between cities and coach operators are required to achieve environmental and operational targets at the city, national and European levels. To explore solutions, a workshop was held at the Breda University of Applied Sciences on 28 May 2024 to explore solutions to enhance the place of coaches in tourism and transport systems through improved coordination, integration of coaches, regulations, assessments and consultations, technology enhancements, communication, and more. Indeed, coaches have long been a non-topic in mobility science and have not yet been the subject of R&I in Europe.

The challenges that coaches face in the urban mobility system relate to space management (parking bays near key destinations), routing and urban vehicle access regulations, poor integration with other transport modes, and drive-train technology options. This is linked with an overall limited understanding of the economic, social and transport systemic contribution of the coach to the urban system.

R&I activities should include:

R&I in this field could focus on developing the value chain stakeholders (cities and coach operators, not the least) to optimise the use of coaches in the urban context. It could centre around five knowledge areas:

- Users: Market segmentation within the coach sector involves understanding diverse user needs and capacities. This includes factors such as willingness to pay, income levels, language preferences, and values such as environmental concerns. Professionals in the coach sector, including drivers and city staff, play crucial roles in ensuring efficient service delivery and addressing user expectations.
- Services: Service models in the coach sector are integral to urban mobility solutions. It's essential to gauge the satisfaction levels of users and stakeholders with the services provided. Integrating coaches into a multimodal mobility system requires seamless coordination to optimise connectivity and accessibility for passengers;
- Vehicle system: Technology options for clean propulsion are critical for reducing emissions in the coach sector. The choice of vehicle technology impacts service models, considering factors such as autonomy, range, connectivity, and the weight and dimensions of coaches. R&I could look at the EU's ability to manufacture zero-emission coaches. New vehicle concepts and accessibility features could be studied. Integration with other heavy-duty vehicle (HDV) systems enhances efficiency and sustainability in transport operations, but is currently not studied;
- Traffic: Efficient routing and access schemes are pivotal in managing coach traffic within urban environments. Understanding the potential of shared infrastructure between PT and coaches can contribute to the overall integration of coaches;
- Integration: Integrating the coach system into SUMPs and in addition developing indicators and data analytics tools can contribute to the improving the role of coaches in Trans-European

Transport Network (TEN-T) Urban Nodes. Effective integration strategies ensure that coaches contribute to achieving mobility goals while meeting environmental and societal expectations.

5.16 Urban mobility in international cooperation

As transport is crucial for shaping cities, mobility energy intensity, and providing access to social and economic opportunities, it also plays a key role in the global climate change mitigation strategy. Developing affordable solutions for low-carbon mobility and fostering the capacity of public and private sector actors to implement these solutions delivers the commitment of the EU to support climate action and also creates opportunities for the European industry to establish co-creation partnerships with counterparts in Africa, Asia and Latin America.

In light of the Team Europe Initiatives[57], closer coordination of research and innovation, development cooperation and climate action activities by the EU and its Member States is required to pool resources and deliver more effectiveness and greater impact. The Global Europe: Neighbourhood, Development and International Cooperation Instrument[58] and its multi-annual thematic indicative programme of Global Challenges[59] is aligned to the commitment and objectives of the 2030 Agenda and its Sustainable Development Goals and the Paris Agreement to shape its support to countries facing long-term development challenges. By 2050, over two-thirds of the world's population will live in urban areas, making cities crucial for the green transition. Global knowledge and normative work are essential for sustainable urban development, prosperity, inclusiveness, and sustainable mobility within and beyond cities.

Future IA could cover a diverse range of solutions for sustainable and low-carbon mobility within the core focus of global cooperation. These actions would aim to foster the capacities of local and national governments in Europe, Asia, Africa, and Latin America in alignment with the objectives of the Paris Agreement, the New Urban Agenda, and the Sustainable Development Goals. Elements from different local contexts that harness the local culture and knowledge and that cater to specific needs and conditions are key in these actions and will strengthen the flows of international cooperation and knowledge creation. For instance, low-technology innovations that are people-centred with strong community engagement in cities of Africa and South America can provide insights to and also benefit from, learnings from the EU to support the uptake of sustainable urban mobility.

Innovation actions must establish robust connections between research, innovation, and development cooperation projects to drive diverse forms of sustainable mobility. This should encompass societal aspects, including skills enhancement, behaviour change, low technology innovations, co-creation, and participatory processes. These connections need to rigorously assess the balance between replication and local context, while providing reference models for replicable decarbonised urban mobility systems integrated into local policies, energy, raw materials, and value chains.

Actions could benefit from the development and implementation of comprehensive lighthouse projects for transformative mobility systems that include urban planning, electrification and decarbonisation, energy

[57] https://international-partnerships.ec.europa.eu/policies/team-europe-initiatives_en

[58] https://international-partnerships.ec.europa.eu/funding-and-technical-assistance/funding-instruments/global-europe-neighbourhood-development-and-international-cooperation-instrument_en

[59] NDICI-Global Europe 'Global Challenges' thematic programme Multi-annual indicative programme 2021-2027

systems and circular economy considerations for at least one large urban area each in Asia, Africa and Latin America. This should consist of feasibility studies built on participatory processes and include aspects of governance, finance, regulation, and technical considerations. These lighthouse projects should build on existing and ongoing activities, should consider including high-capacity sustainable PT routes, and should focus on system integration. Improved conditions for active modes, new mobility services, 2-, 3- and 4-wheelers, small buses and services to enhance the capacity and efficiency of the PT system.

These demonstration actions should also act as a basis for a capacity-building programme for other advanced cities in the respective regions, including capacity-building hubs (at least one each in Europe, Asia, Africa and Latin America) to provide academic and professional training to local authorities, PT operators, e-mobility start-ups and SMEs on innovative mobility solutions in the context of decarbonising transport and sustainable urban development.

Actions must build on previous activities funded by the EU on research and innovation, development cooperation and climate action and further develop partnerships. On e-mobility, solutions should also be integrated into transition concepts for sustainable urban mobility for passenger and freight transport and include public and private sector partners. This would also include new mobility services, Mobility as a Service, integration with renewable energy and local grids, battery concepts and charging infrastructure. Actions should consider policy and finance solutions, and the country selection should consider the energy mix, the regulatory environment, and the replicability of e-mobility innovations. They should also aim to coordinate with EU services, Member State implementing agencies and public development banks to create synergies and foster long-term impacts.

International cooperation should also aim at creating an ecosystem for transformative change in the participating cities in Europe, Asia, Africa and Latin America, which includes sustainable funding mechanisms/sustainable urban finance support, formats for coordination and synchronisation of local and international public and private sector actors to speed up implementation processes of sustainable mobility solutions and complementary measures. The exchange and creation of knowledge must flow in multiple directions, powered by the implementations, practices and experiences taking place in the cooperating cities and countries. This should facilitate partnerships between authorities and entrepreneurs in Europe, Asia, Africa and Latin America.

R&I activities should include:

- Examination of how the differences in context and culture can strengthen international cooperation and knowledge creation by looking at people-centred and low-technology innovations
- Development of guidelines for capacity-building programmes, with global region capacity building and knowledge exchange hubs for the different stakeholders
- Exploration of policy, governance and finance solutions in coordination with EU services and public development banks for long-term impacts

Results are expected to contribute to the following outcomes:

- New collaboration schemes and multi-direction flows of knowledge that consider different aspects of urban mobility, from governance to business models, enriching local and regional solutions and uptakes

MILESTONES FOR INTEGRATED SOLUTIONS

Integrated solutions	Research and innovation topics	Type of action	Milestone
Active travel modes	Development of improved planning and design of active travel infrastructure, considering different approaches to flexible and dynamic street space reallocation, public space quality, shared spaces, kerbside management, and connected routes and networks, with links to urban planning and housing policies in urban, peri-urban and rural areas through living labs, co-creation and public involvement	IA	2030
	Development of new mobility management policies to promote active modes (e.g., flow, speed, traffic lights, parking facilities, land-use prioritisation), particularly considering interactions with other LEVs and powered micromobility modes and the development of supportive innovations in technology and governance	IA	2030
	Research on local cycle ecosystems, considering industry, services, policies and end users, looking into their relevance, enhancement and distribution across Europe	CSA	2040
	Combination of social sciences and technological research to examine choices, behaviours, and perceptions, but also to include the needs of a variety of people, increasing representation and equity in active travel	RIA	2040
LEVs – new vehicle concepts for urban use	Research collecting and analysing evidence of successes and failures, necessary social, ecological and planning frameworks, also including user acceptance factors and diverse user requirements to support the uptake and rollouts of new and innovative LEVs	RIA	2040
Advanced automation in an urban context	Assessment and evaluation of benefits and impacts of different CCAM use cases in integration with urban mobility systems, aiming to reply to the mobility needs and demands of urban, peri-urban and rural, both for passengers and goods	RIA	2040
Integrated solutions: Coach and the city	People and Users: Market segmentation within the coach sector involves understanding diverse user needs and capacities. This includes factors such as willingness to pay, income levels, language preferences, and values such as environmental concerns. Professionals in the coach sector, including drivers and city staff, play crucial roles in		

Integrated solutions	Research and innovation topics	Type of action	Milestone
	ensuring efficient service delivery and addressing user expectations.		
	Services: Service models in the coach sector are integral to urban mobility solutions. It's essential to gauge the satisfaction levels of users and stakeholders with the services provided. Integrating coaches into a multimodal mobility system requires seamless coordination to optimize connectivity and accessibility for passengers.		
	Vehicle system: Technology options for clean propulsion are critical for reducing emissions in the coach sector. The choice of vehicle technology impacts service models, considering factors such as autonomy, range, connectivity, and the weight and dimensions of coaches. R&I could look at the EU's ability to manufacture zero-emission coaches. New vehicle concepts and accessibility features could be studied. Integration with other heavy-duty vehicle (HDV) systems enhances efficiency and sustainability in transport operations, but is currently not studied		
	Traffic: Efficient routing and access schemes are pivotal in managing coach traffic within urban environments. Understanding the potential of shared infrastructure between public transport and coaches con contribute to the overall integration of coach		
	Integration: Integrating the coach system into Sustainable Urban Mobility Plans (SUMPs) and in addition developing indicators and data analytics tools can contribute to the improving the role of coaches in Trans-European Transport Network (TEN-T) Urban Nodes. Effective integration strategies ensure that coaches contribute to achieving mobility goals while meeting environmental and societal expectations		
Urban mobility in international cooperation	Development of guidelines for the planning and implementation of programmes and hubs for capacity building, knowledge exchange and creation, encompassing different stakeholders, exploration of political, governance and financial solutions in coordination with EU services and public development banks for long-term impacts	IA	2040

Table 6 Integrated solutions – milestones

6 LIST OF TABLES

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8 CONTRIBUTORS

ERTRAC Working Groups:

ERTRAC Working Group: Connectivity and Automated Driving
ERTRAC Working Group: Energy and Environment
ERTRAC Working Group: Road Transport Safety & Security
ERTRAC Working Group: Urban Mobility

Leads:

POLIS (Lead of the Urban Mobility Working Group)
UPM (Lead of the Urban Mobility Working Group)

Contributing Associations:

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