Integrated Urban Mobility Roadmap

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Research Advisory
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through Collaboration
in Europe

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0. EXECUTIVE SUMMARY

This report presents a research roadmap paving the way towards an integrated urban mobility system, delivered by the joint Urban Mobility Working Group of ERTRAC, the European Road Transport Research Advisory Council, ERRAC, the European Rail Research Advisory Council, and ALICE, the Alliance for Logistics Innovation.

Urban mobility is vital to European society in providing access to services for passengers and goods and supporting economic growth. European cities are facing similar challenges, such as congestion and pollution, and perceiving similar trends, such as digitalisation, the sharing economy, etc. At the same time, transport demand continues to increase. To manage this increasing demand as well as tackle the related societal challenges, a wide range of complementary mobility solutions and services adopting innovative user-centric, smart, multimodal and intermodal approaches, is required.

This roadmap identifies research priorities related to urban mobility and freight delivery with the aim to achieve a more convenient, competitive, sustainable and resource-efficient mobility system, which is essential to secure a high level of accessibility for passengers and goods as well as economic growth. The roadmap updates, integrates and complements previous roadmaps and reference documents produced by the ERTRAC-ERRAC Urban Mobility Working Group, i.e. 1) **Towards the integration of the urban mobility system**, the joint ERTRAC / ERRAC roadmap of 2011, 2) **Urban freight roadmap**, jointly developed between ERTRAC and ALICE in 2014, 3) **Land Use and Transport Interaction** (2013) and 4) **Road User Behaviour and Expectations** (2011).

All modes of transport and all types of users, vehicles, infrastructures and services are addressed and an overview is provided of mobility services and solutions that offer significant potential to contribute to decarbonisation in view of the European 2050 target.

The proposed research actions involve three aspects: a better understanding of **current and emerging societal trends and challenges**; creating or improving **frameworks/enablers** that remove barriers and/or enhance a more efficient mobility provision and more effective transport policy implementation; and finally identifying **innovative urban mobility solutions and services** to tackle mobility challenges at short, medium and long term and this from an infrastructure, management, services and modes perspective. A distinction is made between RTD, demonstration, deployment/ market introduction and policy development.

This roadmap addresses the main stakeholders of the sector (cities, industry, retail, logistics service providers), and aims to contribute to the definition of research priorities for European research and innovation programmes, including Horizon 2020, the European Framework Programme for Research and Innovation for 2016-2020, and subsequent European Framework Programmes.

1. INTRODUCTION

1.1. Background

ERTRAC, the European Road Transport Research Advisory Council, represents the diverse range of road transport stakeholders and brings them together with representatives from public authorities at the European, national, regional and urban levels. The multi-stakeholder nature of ERTRAC makes it unique in being able to present a holistic and integrated view of road transport issues. ERTRAC's mission is to seize the opportunity for better coordination of private and public research activities, and to make specific recommendations for their implementation. ERTRAC delivers roadmaps for cross-cutting research that provide a reference for the future planning of European and national transport programmes. In addition, it is hoped that this reference provides an overarching framework for research, innovation and technological development, as well as guidance for individual research planning.

For the particular case of the Urban Mobility Working Group, the multi-stakeholder dimension is even more explicit. Given the integrated and essential multimodal nature of the urban transport system, it was decided to adopt a collaborative approach and join forces with the European Technology Platforms ERRAC (rail) and ALICE (freight) for a joint cross-ETP Working Group on Urban Mobility.

Today's and tomorrow's urban mobility system - encompassing all modes of transport - is facing new societal challenges and economic patterns. In order to be able to achieve a more convenient, competitive, sustainable and resource-efficient mobility system as well as guarantee a high level of accessibility for passengers and goods, time had come to produce an updated and integrated ERTRAC urban mobility roadmap that identifies the research and innovation needs that have to be addressed to meet these new challenges and trends.

The aim of this new urban mobility roadmap is to update and integrate previous roadmaps and reference documents developed by the ERTRAC-ERRAC-ALICE Urban Mobility Working Group into one consolidated version, covering the essential elements of today's and tomorrow's urban mobility spectrum. The new roadmap builds on four existing documents, i.e. 1) Towards the integration of the urban mobility system, the joint ERTRAC / ERRAC roadmap of 2011, 2) Urban freight roadmap, jointly developed by ERTRAC and ALICE in 2014, 3) Land Use and Transport interaction (2013) and 4) Road User Behaviour and Expectations (roadmap 2011).

While the aforementioned documents focused on specific areas and particular aspects of the urban mobility system, the integrated and encompassing approach adopted in this new roadmap will ensure their complementarity, establishes the necessary synergies, and accommodates new developments that have emerged since. A single roadmap allows for a better exploitation of all transport modes, services and infrastructures towards enhanced sustainable mobility and greater efficiency, thus paving the way for a new user-oriented urban transport scenario. Updating and integrating the previous urban mobility roadmaps and documents also includes an appreciation of research and innovation projects in the urban mobility field funded through the Seventh and Horizon 2020 Research and Innovation Framework Programmes so far, and the extent to which they addressed research, innovation and deployment priorities identified in earlier ERTRAC urban mobility documents.

Further details on this analysis are available on www.ertrac.org/index.php?page=urban-mobility in the form of overview tables that are being updated regularly.

1.2. Scope

This roadmap addresses the entire urban mobility system, taking into consideration all types of urban transport users, vehicles, modes, infrastructures and services. Public, collective, shared and private transport, motorised and non-motorised (walking, cycling, etc.) trips are considered here. The link between urban and interurban or long-distance transport services is also looked at.

This roadmap not only includes actions to promote modal shift to sustainable transport modes such as public transport and active travel, it also considers the dichotomy between mobility demand and place demand, and aims to establish a better link between urban mobility and land use planning.

Chapter 2 outlines the priorities for urban mobility research. Chapter 2.1 identifies how new and changing societal trends and patterns such as decarbonisation, city dynamics, demographic challenges, digital society, the sharing economy, and automation will generate new urban mobility scenarios and expectations.

Chapter 2.2 defines a set of frameworks and enablers that impact on the way urban mobility can and should be addressed, i.e. Sustainable Urban Mobility Plans, big data and modelling tools, governance, regulation and business models, and transferability, capacity building and upscaling.

Finally, Chapter 2.3 highlights which innovative urban mobility solutions and services are required for a more effective, reliable and energy-efficient urban transport system, ensuring an optimum mix between the various transport options and combining short to medium-term actions with long-term approaches, including services and infrastructures for long-term efficiency. A distinction is made between infrastructure-related solutions, management-related solutions, service-related solutions, and modal solutions.

For each of the research priorities identified under the respective chapters, it is indicated whether the actions required relate more to fundamental research, the deployment of innovation and market roll-out, coordination and pooling of existing research and innovation efforts, and support through for example capacity building.

1.3. Complementarity between ERTRAC roadmaps

This roadmap results from the extensive update and integration of four existing urban mobility roadmaps and documents produced over the last years by the ERTRAC-ERRAC-ALICE Urban Mobility Working Group:

1. **Towards the integration of the urban mobility system/Joint ERTRAC ERRAC roadmap (2011)**
   This document brought together the work on urban mobility of the two platforms to present a coherent and integrated roadmap on the urban mobility system put forward by the stakeholders of the rail and road sector. Research topics of this roadmap which haven't been addressed by European research and innovation projects in the meantime, have been updated and integrated in this new roadmap.

2. **Urban Freight Research Roadmap (2014)**
    This document is a research roadmap on urban freight and logistics delivered jointly by

ERTRAC and ALICE, the Alliance for Logistics Innovation through Collaboration in Europe. As this roadmap is quite recent, it remains a very valid reference document, and therefore the research topics in the field of urban freight, included in this new roadmap focus on those areas which in the meantime have been identified by ALICE and the ERTRAC Urban Mobility Working Group as additional remaining gaps to be addressed.

3. **Land Use and Transport Interactions (2013)**
This integrated research initiative on land use and transport interactions (LUTI) addressed the reciprocal interactions between land use and surface transport, both from the infrastructure side and mobility side, for freight as well as passengers. These topics are addressed in 2.1.2 City dynamics, 2.2.1 SUMPs and 2.3.1 Land use and transport interaction.

4. **Road User Behaviour and Expectations (2011)**
The primary objective of this roadmap was to provide guidance on analysing road user behaviour in terms of user needs, preferences and expectations to build an improved road transport environment for passengers. Cross-cutting elements of this document have been taken up throughout this new roadmap whenever relevant.

1.4. Policy background and high-level targets

This roadmap builds on the high level **ERTRAC Strategic Research Agenda 2010** "Towards a 50% more efficient road transport system by 2030". It is ERTRAC's firm belief that a European road transport system that is 50% more efficient than today could be achieved by 2030, by adopting the range of research and innovation priorities as defined in the Strategic Research Agenda[1].

This ambitious headline objective guides ERTRAC's contribution to Europe's efforts to address the 'grand challenges of our time', and to bring sustainability to the European community (Lund, 2009). This contribution involves bringing significant improvements to the European road transport system. The research and innovation proposed in the ERTRAC SRA will enable such improvements by addressing the broad range of challenges related to the road transport system, including: the supply of energy and resources; global climate change and the environment; health and safety; and increased global competitiveness of the road transport industry leading to economic growth and high quality employment in Europe.

The approach taken by the SRA recognizes, in particular, the societal demand for decarbonisation, reliability and safety of the road transport system from a user's perspective. For each of these societal needs, clear indicators have been selected, each with specific guiding objectives towards 2030. Referring to decarbonisation in particular, a major priority in the EC's recently published Strategy for Low-Emission Mobility (see below), a dedicated Evaluation Group has been set up in ERTRAC, which is quantifying the CO_2 reduction potential of innovative road transport measures, including urban transport measures.

Within a broader EU policy context, this roadmap takes into account the priorities and targets as outlined in the European Commission's Transport White Paper and Urban Mobility Package. In 2011, the European Commission published its Transport White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource-efficient transport system", with the aim to move Europe to a more efficient and competitive transport system and achieve

a 60% reduction in greenhouse gas emissions by 2050. The White Paper sets out ten key goals for Europe's transport system, some of which relate to urban mobility (European Commission, 2011):

• **Halve the use of 'conventionally fuelled' cars in urban transport by 2030, phase** them **out in cities by 2050** and achieve **near CO$_2$ -free city logistics by 2030;**

• Establish a **fully functional and EU-wide multimodal TEN-T 'core network' by 2030** that has been adjusted to recognise key city nodes on the network;

• Establish the framework for a **European multimodal transport information, management and payment system** that is relevant for urban ITS **by 2020;**

• Move **close to zero fatalities in road transport by 2050 and halve road casualties by 2020;**

• Move towards the full application of the **user and polluter pays principles** relating to urban road pricing and public transport pricing.

In view of the economic importance of urban areas in Europe and the associated transport problems in these areas, a consensus emerged that EU transport policy needed to have a much stronger urban element. This is also reflected in the European Commission's **Urban Mobility Package of 2013**. Building on the White Paper, it stipulates that "a step-change in the approach to urban mobility is needed to ensure that Europe's urban areas develop along a more sustainable path and that EU goals for a competitive and resource-efficient European transport system are met" (European Commission, 2013, p. 3). The Mobility Package identified **five key areas for action:**

• Increased implementation of SUMPs,

• More action on urban logistics,

• Smarter urban access regulations and road-user charging,

• Coordinated deployment of urban intelligent transport systems,

• Additional effort to enhance urban road safety.

Other recent European policy initiatives also influence and contribute to shaping the urban mobility debate, setting certain priorities, and working towards certain targets, including:

• **The European Directive on the framework for the deployment of intelligent transport systems in the field of road transport and for interfaces with other modes of transport:** It seeks to encourage the development of innovative transport technologies to create ITS. This is done by introducing common EU standards and specifications which aim to establish interoperable and efficient ITS services, while leaving EU countries to individually decide which systems to invest in (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:207:0001:0013:EN:PDF);

• **The European Directive on the deployment of alternative fuels recharging and refuelling infrastructure:** it requires Member States to develop national policy frameworks for the market development of alternative fuels and their infrastructure, foresees the use of common technical specifications for recharging and refuelling stations, and paves the way for setting up appropriate consumer information on alternative fuels, including a clear and sound price comparison methodology (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:3 2014L0094&from=EN);

• **The European Innovation Partnership on Smart Cities and Communities (EIP-SCC):** this initiative brings together cities, industry and citizens to improve urban life through more sustainable integrated solutions. This includes applied innovation, better planning, a more participatory

approach, higher energy efficiency, better transport solutions, intelligent use of Information and Communication Technologies (ICT), etc. (https://eu-smartcities.eu/about/useful_links)

- **European Strategy for Low-Emission Mobility**: this recent communication was presented by the EC in July 2016. It states that "low-emission mobility is an essential component of the broader shift to the low-carbon, circular economy needed for Europe to stay competitive and be able to cater to the mobility needs of people and goods". With transport representing almost a quarter of Europe's greenhouse gas emissions and being the main cause of air pollution in cities, Europe's answer to these challenges is a shift to low-emission mobility and the ambition to have at least 60% less greenhouse gas emissions from transport by the middle of the century compared to 1990 and a drastic reduction of air pollutants from transport which are harmful to citizens' health. It stipulates that "transport has much greater potential than in the past to contribute towards reducing the EU's emissions, as we have committed to do under the Paris Agreement on climate change and in line with the 2030 Agenda on Sustainable Development." (http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52016DC0501)

1.5. The city of today and tomorrow

The global population has tripled over the last 100 years, with over 7 billion people today and a world population that will continue to grow in the coming years. Forecasts for 2050 suggest numbers of 9 to 11 billion people. Cities are and will continue to become more densely populated. In 2016, there are more than 20 megacities with more than 10 million people. The trend towards urbanisation coupled with population growth continues.

Modern-day megacities like Mumbai, Beijing and Mexico City offer a glimpse of the complexities of living, working and moving in cities, which are likely to become widespread. Future mobility projects will have to solve a host of complex issues, including congestion, pollution, access and gridlock.

Transport is a key enabler of social and economic development, with the transport sector accounting for 9 million jobs across the EU. 68% of EU citizens live in and a high proportion of economic activity takes place in urban areas (85% of EU GDP), which means that problems with urban transport infrastructure can have serious economic consequences. Road congestion in the EU is often located in and around urban areas and costs nearly €100 billion every year, in other words, 1% of the EU's GDP. Urban areas are also particularly exposed to road congestion and higher levels of air and noise pollution, and are below average in reducing road fatalities (Source: European Commission, 2013, Special Eurobarometer 406 – Attitudes of Europeans towards Urban Mobility, p.2).

The 2013 Eurobarometer on Attitudes of Europeans towards Urban Mobility revealed that half of Europeans use a car every day, which is more than the proportion who cycle (12%) or use public transport (16%) together. Nearly nine out of ten Europeans experience problems when travelling within cities that can limit their access to important goods and services. A substantial majority of Europeans believe that air pollution, road congestion, travelling costs, accidents and noise pollution are key problems within cities. The importance of lower public transport prices suggests that costs are a sensitive issue for mobility. The European public does support alternative forms of urban transport. The most frequently cited support measures include better public transport and improved walking and cycling facilities, as well as restrictions on the use of certain vehicles such

as trucks and incentives for car sharing and carpooling schemes. Less than a quarter of Europeans believe that the urban traffic situation will improve in the future and most believe it will stay the same or get worse. This indicates that measures to improve urban mobility are of critical importance. It is remarkable to see the substantial variety of situations and perceived problems across countries, and measures to improve urban mobility will therefore need to be designed and adapted to local circumstances (European Commission, 2013).

Already today, European Cities face a strong need to reach policy goals regarding for example emissions (CO_2, NOx, noise etc.) and public space, balancing mobility needs with quality of life and sustainability. Space becomes scarce while mobility demand continues to increase. Accessible, safe and environmentally friendly urban mobility services need to be secured, while increasing numbers of citizens will have to share the available transport infrastructure. On a global scale, cities and industry are developing coherent operational tools and solutions to better plan and manage the urban territory and improve the quality of life of citizens. These tools are the practical translation of a deeper understanding of interdependencies and synergies between sectors such as transport, energy, urban planning, economic development, environment, health, etc.

The transport sector leaves ample room for improvement in terms of (energy) efficiency, environmental performance (air quality and noise) and leverage for economic development. For several of these objectives, actions in transport will be more cost-efficient compared to other forms of urban infrastructures and sectors, where quick wins have already been made and low hanging fruit has been harvested. The urban transport field in particular can and should contribute to realising EU policy goals, whether they are on an overarching strategic level (jobs and growth, energy targets), or relate to targets applied to transport specifically (road safety, 2030 clean city logistics, etc.).

Personal mobility is one of the main enablers for human interaction, knowledge transfer and relationship-building. Over the last 120 years, the private automobile has been a major pillar of personal transportation, contributing to higher degrees of accessibility, social and economic prosperity, convenience and human interaction. However, with a growing urban population and resulting increasing demand for transport in urban areas, the equivalent expected increase in numbers of privately-owned cars leads to chaos within urban traffic, impossible requirements for urban parking space, and severe air quality and noise problems. These major challenges need to be addressed through solutions promoting modal shift towards public transport, shared mobility and light modes and a host of opportunities enabled by dedicated policies, technologies and entrepreneurial innovation resulting in new mobility models that incorporate the needs of citizens, communities and the planet, especially regarding pollution and space allocation in urban areas. A good quality of life in cities indeed implies space for people, fewer cars and reduced congestion, an increased high quality range of sustainable mobility options and services organised in a modern way, and less air and noise pollution.

Additional challenges are pointed out by the Joint Programming Initiative Urban Europe, which refers to the notion of "metapolisation", i.e. the expansion of urban ways of life beyond urbanised. This involves a radical shift in the size of urban regions and daily transport infrastructures, a transformation of daily (ways of) life and mobility practices, cultural transformations in value systems and attitudes to cities, the countryside and nature, and raises environmental and governance challenges. JPI Urban Europe also states that larger metropolitan areas have become

increasingly polycentric, as more and more activities progressively relocate outside the centres of agglomerations. This structural transformation from mono- to polycentric urban areas is reflected in patterns of daily travel behaviour: the share of daily trips between peri-urban, suburban or even exurban locations is increasing, to the detriment of trips to or from the centre of agglomerations. Long-distance commuting from one urban region to another is also increasing. (JPI Urban Europe, 2015).

The transport sector is currently shaping and experiencing a paradigm shift, with coinciding transitions in the field of energy use (electrification), technologies (ITS, RTTI), and behavioural change (sharing economy, focus on active travel). These changes affect passenger, as well as freight transport, business as well as leisure travel.

People mobility in the city of tomorrow will be increasingly intermodal, with a balanced combination of soft and light modes, different, complementary types of public transport solutions, new mobility services, shared and private vehicles. Complementary solutions will be operating in an integrated seamless way, supported by advanced pervasive information, often co-created by connected people when moving around. Time spent in transport or in modal interfaces will be more usefully spent, and the travel experience will be made much more pleasant.

At the same time, the economic importance and evolving requirements, as well as the potential adverse impacts of goods transport in urban areas also need to be carefully considered. As highlighted in the Research Theme Analysis Report on urban mobility of the Transport Research and Innovation Portal, the changing needs of urban freight (e.g. as a result of e-commerce) need to be taken into account in land-use and transport planning, as well as in local economic development strategies. There is a need to develop adequate and appropriate infrastructures and solutions that support new developments in the urban freight field, such as consolidation, electrified and light urban delivery vehicles, the roll-out and management of business models for charging infrastructure, integration of urban freight in urban network management, including data collection and sharing. (Transport Research and Innovation Portal, 2016, Research Theme Analysis Report Urban Mobility).

A changing mobility paradigm that properly tackles today's and tomorrow's challenges and accommodates current and emerging societal trends will clearly require research into new mobility scenarios, technological innovations, additional mobility services and solutions. This urban mobility research roadmap looks at the urban mobility implications of decarbonisation, city dynamics, demographic challenges, digital society, the sharing economy and automation. At the same time, it reflects on the potential and further research needs of frameworks and enablers for urban mobility, such as Sustainable Urban Mobility Plans (SUMPs); big data and modelling tools; governance, regulation and business models; transferability, capacity building and upscaling. Innovative urban mobility solutions and services that require further research have been identified in relation to infrastructure (land use and transport interactions, interchanges, optimised use of infrastructures), management (demand management, integrated urban mobility and network management, integrating urban mobility within the overall European transport chain), services (integrated information, integrated payment, urban freight and logistics) and modes (clean fuels and vehicles, active and light travel modes).

2. RESEARCH NEEDS, PRIORITIES & MILESTONES

2.1. Changing societal trends – new urban mobility scenarios

This chapter identifies new and emerging societal trends and challenges, such as decarbonisation and air quality, patterns of urbanisation and resulting city dynamics, demographic changes (e.g. ageing population), digitalisation, the sharing economy, and automation. It defines what is required to enable future urban mobility scenarios that meet the demands of tomorrow's society and economy. Depicting new urban mobility scenarios will help to understand these challenges and adapt requirements for all modes of transport and for different types of users.

Research on new urban mobility scenarios should consider all aspects of these societal trends, and address the provision of new urban mobility services in addition to the conventional transport supply. This will also help to provide tailored transport services for all user groups and reduce social exclusion.

2.1.1. Decarbonisation and air quality

The Europe 2020 Strategy for smart, sustainable and inclusive growth includes a specific target for decarbonisation, which is to reduce greenhouse gas emissions (GHG) by 20%, increase the share of renewables in the EU's energy mix to 20%, and achieve the 20% energy efficiency target by 2020 (European Commission, 2011). Together with the White Paper on Transport and the Energy Efficiency Plan, it aims to reduce GHG emissions from the transport sector with 60% by 2050 compared to 1990 and with 20% by 2030 compared to 2008 levels. The COP21 Paris Agreement of December 2015 paved the way for global CO_2 mitigation efforts by setting up a five-year review cycle for national decarbonisation commitments starting in 2020.The importance of speeding up decarbonisation efforts post COP21 is reflected in the recent EC communication on low-emission mobility of July 2016 (European Commission, 2016). This communication is considered to be a cornerstone of the EU policy framework for the next five years for clean transport. ERTRAC has made the decarbonisation of transport one of its strategic priorities as well, and has established a dedicated Evaluation Group that will assess the decarbonisation impact of a wide range of transport measures and solutions. To help close gaps between commitments and delivery on climate change mitigation, the International Transport Forum is also proposing a comprehensive project to help decision-makers meet their objectives to decarbonise transport (www.itf-oecd.org).

The transport sector has experienced difficulties with decarbonising and lags behind non-transport mitigation with 10-30 years. Integrated and strict policy solutions are required to meet the increased pressure on urban energy infrastructures as well as the need for measurability and accountability to policy interventions. Moreover, an efficient integrated and low-carbon urban mobility system will be achieved only if the user perspective has been well considered, and all types of citizens are included, not only improving transport reliability and urban accessibility, but also social inclusion.

Air quality in urban areas also poses a major challenge because large shares of the urban population are suffering from exposure to pollutant levels above health limits, particularly with respect to NOx and PM. Policy measures should therefore address both decarbonisation and air quality targets in an integrated way, for passengers as well as goods.

Thus, **research actions** should cover the development and integration of the following issues, both for passengers and freight:

- Develop **more efficient policy interventions** by studying current modal split and travel patterns;

- New **assessment methods** to evaluate the impacts of innovative policy measures on decarbonisation and pollutant emissions and to understand trade-offs between energy reduction and other urban mobility targets;

- Promote **eco-driving and eco-routing** to change driver behaviour;

- Assessment of impacts of new technological changes (smart cities, digital society, e-commerce) on GHG and pollutant emissions;

- Improve **quality of vehicle fleets** by:

  > Reducing the total number of cars and particularly the number of old cars via age limits, taxation, or access regulations;

  > Fostering the change to clean vehicles and fuels, in particular electric vehicles, through market promotion, subsidies for replacing polluted vehicles, parking incentives, etc.;

  > Promoting the acceptance and use of greener fleets and higher capacity means.

- **Rationalise** the use of cars:

  > Develop new interconnections of cars with other modes, integrated with public modes and innovative mobility concepts and services that incorporate flexibility, quality, efficiency and affordability;

  > Reduce vehicle-kilometres, through less parking searching, reducing empty vans and promoting high occupancy vehicles, car sharing, public transport and active and light transport means;

  > Modal shift through measures such as pricing schemes, public transport promotion (fare, frequency, reliability), higher share of non-motorised modes, etc.;

  > Identify packages of measures to promote intermodality.

[EXPECTED IMPACTS]

- Cleaner vehicle fleets,

- More intensive and efficient use of transport modes,

- Less car dependence for urban mobility, both for freight and passengers.

2.1.2. City dynamics

Cities evolve over time with changes in factors such as the size and characteristics of the population, and land use. There is growing competition between European cities to attract business and tourism, and this brings about both opportunities and problems. Many European cities are facing serious challenges with regard to demographic changes, energy efficiency needs, land-use efficiency needs, diversity and integration, inclusion of all population groups, municipal liabilities, requirements for environment protection, and the establishment and promotion of sustainable urban lifestyles.

The dynamics of economically strong urban areas are leading to significant growth, increasing scarcity of public space, and more congestion and emissions. In such situations, an increase in the efficiency of the overall transport system is of key strategic importance, as the potential for major new transport infrastructure implementation is limited by both cost and the urban fabric itself. Efficiency can be achieved through a better provision of different forms of mobility as an integrated service, emission-free drive trains and by making public transport the backbone of the urban transport network. Large-scale implementation and integration of these different aspects is required to address the problems effectively and generate significant relief effects. The priority allocated to public transport must increase with the size and density of cities, especially through dedicated infrastructure for public transport in major cities, such as Bus Rapid Transport, Light Rail, automated metro, regional and suburban services and their combination. The role of cities, when their size increases, has to be analysed at the national level, European level, and for the multimillion population cities even also at the global level.

Some urban and regional areas are facing shrinking tax revenues and reducing populations as a result of migration. In such areas, lower municipal revenues will make it increasingly challenging to maintain the current infrastructure endowment in general and transport infrastructure in particular.

Still, almost three quarters of Europe's population lives in cities, towns and suburbs. Recent decades have experienced a trend back to the inner cities – re-urbanisation – at least to the vibrant inner cities. At the same time, most cities have been experiencing urban sprawl with housing, jobs and commercial activities located in increasingly dispersed suburbs. Marketing strategies of city governments have been keen to improve the image of agglomerations and thereby further reinforce the qualitative attractiveness of urban areas. Re-urbanisation has led to increasing pressure on land and capacity constraints for transport services, particularly in city centres. Further conflicts and competition between transport modes (incl. for parking) and land use (transport versus other functions) can be expected.

Many mobility solutions have been developed to address growing demand, but there is a lack of solutions for areas where overall travel demand is stagnating or decreasing such as in less densely populated or peri-urban areas. Traditional public transport is rarely economically sustainable in these areas. The potential for the deployment of automated shared driving is linked to urban density since such a service will be more sustainable in cities. However, the limit for implementing automated shared transport systems in terms of population density and land use patterns is unknown. Nonetheless, new mobility services and shared mobility can provide new ways of addressing demand in less densely populated areas or in regions where demand is shrinking.

The above trends are confirmed by the observations of the JPI Urban Europe Initiative, which stipulates that European patterns of urbanisation rest upon a dense network of predominantly middle-sized cities, which has developed incrementally/progressively over a very long period of time. It is stated that the European population is now largely urbanised and the growth of urban populations limited. There is, however, significant migration towards wealthier cities, meaning that some of the origin cities and regions are depopulating. In most cases a process of suburbanisation

is at work: population increases tend to occur predominantly in the outer parts of urban areas, sometimes in remote, low-density areas distant from the main urban agglomeration on which they depend, while populations in urban centres remain constant or reduce. The ancestral distinction between the urban and the rural is dissolving; and the urban condition increasingly diffuses to non-urban areas through the expansion of transport, telecommunications and utility infrastructures and the ever increasing distances of daily mobility. (JPI Urban Europe, 2015).

The research challenges with regard to city dynamics, growth and shrinking should explore trends and provide initial ideas for solutions adapted to various sizes of cities and their relevant economic role at local, national, European and even global level.

Key topics can be allocated to the following research areas:

- **Understanding people's needs and wishes**, including those of specific groups such as recently immigrated and low-income citizens;
- Investigating in transport systems for **more efficient use of space** and balancing temporal and spatial priorities between modes and land uses and understanding the different sizes and scales of cities and their impact on mobility services;
- Analysing mobility concepts that promote **'active' and safe mobility**;
- Exploring the potential role of **neighbourhood-based solutions** and services;
- Investigating into approaches to **increase capacities of travel modes**, focusing on public transport and intermodal options;
- Smart solutions **using ITS and big data to tackle growing demand** without substantial investment into infrastructure. More research is needed to investigate the actual efficiency benefits of such technologies and to what extent they can replace infrastructure development;
- New **assessment methods** to detect the re-urbanization, densification and shrinking processes;
- New disruptive technology and land use **measures to control urban sprawl** or to reduce the speed of urban sprawl, including increased attractiveness of existing urban areas;
- Possibility of **sharing uses of urban land**: shared parking for different activities along day/week days (offices, shopping, sports).

[EXPECTED IMPACTS]

- Better and more balanced use of urban space,
- More attractive cities for living and economic activities,
- Integrated planning of land uses and transport networks,
- Tailoring neighbourhood solutions for passenger and freight mobility.

2.1.3. Demographic challenges

Metropolitan areas offer jobs, cultural life, social exchange and infrastructure, for example health infrastructure. Economic concentration, the ageing of European societies, and continuous migration to Europe may be further drivers for continued urban densification. Ageing is one of the greatest social and economic challenges of the 21st century for European society that will affect most policy areas. By 2025, more than 20% of Europeans will be 65 or older, with a particularly rapid increase in numbers of over 80[2]. Older people are most likely to experience mobility difficulties. A reduction in mobility can impact the quality of life and psychological well-being at an older age. The ageing of society therefore also brings new demands for mobility and accessibility in urban areas, especially in areas that are perceived as unsafe.

The transport industry and policy makers have to be fully aware of the challenges related to an ageing society. Even in quite developed urban environments, there are not only physical accessibility barriers, but also with higher levels of intermodality, including transferring at interchanges, moving becomes more complex and rather difficult for older people. New, innovative solutions are required for rendering connections smoother and more natural and to provide much better intermodal interfaces.

Therefore, there is a need for new research to better understand user needs of older people, taking into consideration their lifestyle (being the first generation used to driving a car, but also being familiar with smart phone, social media and shared economy). The latest technologies may provide many possibilities for urban mobility solutions that can help to address the challenges of ageing society and serve the specific needs of older people. In the future, the issue of an ageing work force and older employees will also come into view.

New Demand Responsive Transport (DRT) solutions need to be designed and deployed, possibly integrating quite different types of mobility services, and considering the specific requirements of this population category, as well as the fact in general that they have higher levels of flexibility (e.g. in terms of time schedules). Moreover, information requirements may be quite different from standard solutions, requiring innovative approaches that take into account possible limitations and cognitive aspects of the users concerned. Ergonomic solutions have to be designed based on the (usually lower) digitalisation level of this rapidly growing group of people.

Furthermore, migrants with different cultural and ethnic backgrounds may also have particular needs with regard to mobility. This becomes increasingly important when considering that some of these groups tend to concentrate and thus alter mobility demands on a neighbourhood level.

The key principles in urban mobility to tackle demographic challenges related to an ageing society and migration are:

- To make driving safer for older people,
- To make taking public transport and active travel safer, more comfortable and easier for older people,
- To offer special mobility services for older people and migrants,
- To facilitate social integration of migrants through inclusive management of transport services.

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[2] http://ec.europa.eu/health/ageing/policy/index_en.htm

Proposed research activities are:

- To gain a more **comprehensive and holistic understanding** of the challenges of ageing and migration on urban mobility and future needs for mobility policies, technologies and services;

- To collect a large amount of **real time data** to understand driving behaviour of older drivers and use the data to **develop driver support systems** specifically helping older drivers to drive more safely;

- To identify **special requirements** of older drivers on driving, information provision (e.g. navigation system) and parking;

- To identify how transport services can play a significant role in helping older people to stay active and independent for a longer time, and to integrate migrants in **economic and social life**;

- To assess the potential of **automated and driverless people movers** for older people with reduced mobility;

- To study how to maximise the benefits of **shared mobility services** enabled by social networks and smartphones to meet needs of older people so as to help cities prepare the necessary legal and legislative framework for such mobility services;

- To provide a network of public transport with efficient services and to exploit potential benefits of **Mobility as a Service** (MaaS) to help older people to stay active;

- To **adapt public transport services** to older people and people with other culture backgrounds;

- To promote (safer) **cycling and walkin**g among ageing and migrant population, also by linking into to societal health challenges such as the lack of physical activity and obesity;

- To analyse the **mobility impact of other demographic challenges** and changes such as composition of population, family size, individualism, combining family with working life, etc.

[EXPECTED IMPACTS]

- Develop a full understanding of the impact of demographic challenges on urban mobility,

- New mobility solutions like shared mobility to meet the specific requirements for older people and immigrants,

- Higher share of public transport, active travel modes and mobility services for ageing and migrant population.

2.1.4. Digital society

Information technologies and digitalisation are quickly and constantly changing our society. The digital era is transforming both our understanding of society and travel needs and the solutions to serve a sustainable urban way of life and development. Access to big amounts of data provides a base for a more intelligent provision of services, catering for different types of users and mobility needs, both for passengers and goods.

>> MOBILITY AS A SERVICE <<

New expectations related to transport of people and goods are emerging. The concept of "transportation" based on a modal approach is evolving into the wider concept of mobility based on a service approach, i.e. the management of Mobility as a Service (MaaS). Nowadays, society is prioritising the customer experience over vehicle ownership and reconsidering the use of various transport modes. In addition, many citizens are favouring a shared or collaborative economy, meaning that for more and more people the ownership of a private car is no longer a primary objective for travelling, especially in urban areas. At the same time, new travel products are made available to the connected customer. This contextual change will completely modify the mobility offer, as well as the payment of mobility services. It will also allow for the easier implementation of strategies for the internalisation of external costs in transport related domains.

The emerging passenger travel services (such as car- and bike-sharing, ride-sharing and ride-selling) will have a positive impact on urban mobility, as long as they reduce the number of private cars and traffic congestion in dense urban areas. At the same time, new logistics needs (due to the internet economy) have to be served without creating new traffic problems and externalities.

The key concept behind MaaS is to put the users, both travellers and goods, at the core of transport services, offering them tailor made mobility solutions based on their individual needs. This means that, for the first time, easy access to the most appropriate transport mode or service will be included in a bundle of flexible travel service options for end users. They include public transport, car-sharing, rental car service, taxi and bike sharing schemes in an integrated way. All the services are paid through one single invoice, with 24/7 support and bonus for sustainable choices. The inspiring results from pilot experiences show MaaS indeed helps to reduce car ownership with a resulting decrease in emissions. This new ICT supported mobility should therefore encourage the provision of better mobility services adopting a user-centric approach.

This approach might however be hampered by a continued (and even growing) digital divide in society. Also the risks due to a latent fragmented market can delay the deployment of MaaS. The users and operators must be able to have all confidence in services and digital platforms, also in terms of quality, privacy and security of data provided.

MaaS has three dimensions that should reappear in related research and innovation activities:

1. The **technological dimension**, including data sharing, interoperability, standardisation. - using connectivity and built-in sensors of smart devices supporting MaaS (smartphones, smart watches, etc.) to derive reliable on-trip information (e.g. actually taken bus line and route) on mobility behaviour in real-time to improve and integrate into existing MaaS and as a data basis for future services.

2. The **behavioural impact**: how do travel and logistics patterns change (e.g. for older travellers), what is the modal shift potential? How does this relate to car and driver license ownership?

3. **Economic and policy dimension**, including organisational and regulatory aspects. This might involve a change of roles of different players involved.

>> DIGITAL LIFESTYLES <<

Passenger car and truck developments go from connected to automated and robotised vehicles.

The impact of new digital technologies (such as MAAS, C-ITS and automation) should also be described in terms of social inclusion. Social challenges and solutions to serve the mobility needs of non-connected citizens, be they called "people with reduced digital mobility" (PRDM) or "digitally disabled people" (DDP) should be addressed.

In order to reach the full potential of **ITS applications**, certain barriers need to be overcome. These relate to **technical challenges, user acceptance, business models and legal issues**. There is a need for research activities that improve certain technical aspects of ITS, for field tests and simulations, and behaviour and usage aspects. Market aspects related to system deployment and business models should also be investigated[3].

The **impact of these developments on the safety of vulnerable road users (VRU)** needs to be understood. Research on the interaction of connected and automated cars with all types of VRU is of great relevance. Key factor in that respect is awareness-raising, in order to improve mutual understanding between all traffic participants of intelligent transport systems used.

Next to that, **detectability and visibility technologies of VRU** are considered to have high potential to increase traffic safety and should be studied further.

Regulatory issues need to be solved, e.g. the mobile devices used by VRU. The **HMI** (human machine interaction) needs to be optimised to reduce risks of distraction. The cognitive load of different types of VRU therefore needs to be assessed. Surely there is also a future for **smart eyewear devices**, in addition to the more traditional hand-held devices and infotainment systems.

To be able to assess the way in and extent to which increasing use of **e-commerce** will impact on urban mobility, it is necessary to understand the behaviour and the reactions of all involved stakeholders, such as consumers, retailers and logistics companies. The acquired knowledge on behaviour and behavioural change has to become part of the evaluation of effects and impact of policy measures. This has to be done by ex-ante assessment. This will inform local policy as to how to develop sustainable strategies on changes and effects of e-commerce and online shopping.

Based on these observations, **research activities should cover**:

- Developing **integrated solutions using big data**, involving close cooperation between public and private actors;
- Innovative **digital mobility platform** with the support of government as third parties;
- New **business models** to address the challenges associated with future integrated urban mobility solutions;
- Impact assessment on the **decline of car ownership and emission reduction** in relation to the implementation of **MaaS**;
- Understand **user needs and expectations** and study their satisfaction degree with using certain MaaS;

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[3] Based on VRUITS, Deliverable D6.2 Recommendations for actions at EU level and their assessment. March 2016

- Study the impact of **detectability and visibility technologies of VRU** to increase traffic safety;

- Assess the impact of new digital technologies (such as MAAS, C-ITS and Automation) in terms of **social inclusion**;

- Study the current environment of the e-commerce market. Detecting and predicting the further development of **e-commerce** and online shopping in Europe;

  > Investigating **consumer needs and expectations** to e-commerce in relation to urban mobility as well as the behaviour of actors in retail, logistics and delivery;

  > Understand the **trends** in and **dynamics** behind e-commerce and its influence on all parts of urban supply (retail logistics, last mile distribution and home delivery, private shopping trips) and their interrelation;

  > Research into the **influence** of e-commerce **on urban shape and land use**, including the changing demand for retail space and logistics areas;

  > Evaluation of impact of the e-commerce growth over **logistics design aspects** in urban planning (loading/unloading areas, consolidation centres, pick up points, warehouses, etc.) and urban design adequate to (evolving) dynamics of urban delivery services.

[EXPECTED IMPACTS]

- Improve public transport efficiency with the complement of other mobility solutions,

- Integrated MaaS with a user-centric approach, enabling a truly integrated urban mobility system, with great benefits to the users and to accessibility and sustainability,

- Better knowledge-based, decision making system supported by big data (digital level),

- Changes in urban deliveries and their effects on city infrastructures for freight,

- New business models both for passenger mobility and freight distribution.

2.1.5. Sharing economy solutions

>> SHARED MOBILITY SOLUTIONS FOR PASSENGERS <<

A new area of shared-mobility services has emerged, essentially representing four key categories: car-sharing, ride-sharing/carpooling, bike-sharing and the sharing of parking spaces. It is expected that these new services will play a significant role in shaping the future of urban transport. Sharing economy approaches are essentially sustainable because they make better use of existing capacity and require only limited investments in new infrastructure.

There is a synergy between membership of shared mobility services and decreasing car ownership rates. Flexible and stationary car and bike sharing schemes pursue the same objectives: to offer attractive mobility services that could supplement the traditional public transport supply and enhance multimodal and intermodal mobility.

Car sharing schemes, either stationary or fully flexible, as they are in place today in many European Cities (DriveNow, Car2Go, Flinkster, CAMBIO, Multicity, ZipCar, …) are only the beginning. Several

derivatives of sharing systems, both for cars and bikes, will complement the sharing offer, for instance peer-to-peer car sharing or ride sharing. In order to harmonise citizens' preferences for multimodal mobility, a cooperative framework involving all stakeholders is required that will help to reach the necessary critical mass and enhance user acceptance.
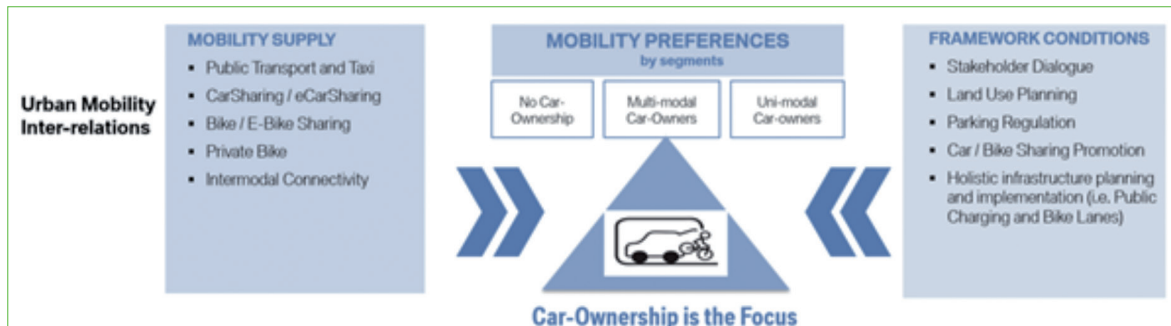
Shrinking numbers of private vehicles in cities are reducing traffic, congestion, parking-space searching and emissions. To achieve a real change in the urban environment however, multimodal mobility offers need to be scaled up and framework conditions for private car ownership must be adapted in order to reflect the scarcity of public space. As a result, the attractiveness of alternative mobility services will increase. Sharing systems, combined with appropriate adapted framework conditions and connected with other transport networks (e.g. public transport, TEN-T, etc.) generate possibilities to help achieve the vision of low polluted cities with redesigned streets for more attractive urban public areas and improved quality of life.

In their various forms, car and bike sharing schemes and their integration into the wider mobility system still pose quite some challenges. **The following issues require further research:**

- The actual **acceptance and take-up** of shared systems;

- **Behavioural aspects** need to be carefully studied and addressed, including the question of sharing limited, non-controlled spaces (as it is the case for carpooling or shared taxis) and how to change some habits and expectations of people moving in urban environments;

- Adapted **regulatory** frameworks;

- **Integration** of shared mobility schemes into larger intermodal systems that need to be designed, deployed and managed in integrated harmonised way, to avoid fragmented, and thus less effective solutions. This will require higher levels of planning and scheduling activities as a way to efficiently use the physical resources available (vehicles, drivers, etc.) and an understanding of the reliability and replacement capacity of shared systems;

- New **optimization and simulation tools** should be developed to provide the right decision-making support for the different stakeholders involved in the process (passengers, vehicle operators, drivers, etc.). Here as well the relation with future automation of vehicles should be integrated;

- Collecting and producing **information** and providing it to the users in an adequate and timely way;

- Generating **Key Performance Indicators for shared mobility services** in terms of sustainability and externalities;

- The articulation of individual demands and expectations is clearly a key aspect of these new mobility systems, requiring the design of more **interoperable and advanced information systems**, strongly based on collaboration and on the co-creation of knowledge;

- Collecting best practice on **business models and tendering for sharing schemes** and **harmonised data collection** to allow for benchmarking;

- Better insights into the actual impact of shared mobility on space use, congestion instead of car ownership:

[EXPECTED IMPACTS]

- The various forms of car and bike sharing become strong and accepted transport means in the urban domain,

- Availability of corresponding infrastructure and implementation to support car and bike-sharing,

- Improved understanding of user behaviour and acceptance of shared mobility services,

- Complementarity with public transport provision,

- Integration of intermodal complementary systems.

>> NEW COLLABORATIVE BUSINESS MODELS OF SERVICES BASED ON SHARING ECONOMY FOR URBAN FREIGHT <<

Consumers and other stakeholders are showing a strong interest in the sharing economy. Re-thinking the value of "ownership" and favouring the one of "use" is the new disruption, especially in urban logistics. There is a need to find new approaches and identify the unexplored potential of emerging peer-to-peer (P2P) business / business–to–consumers (B2C) opportunities in the freight market, and to make them more attractive and widely accepted. Solutions should increase reliability, trust in transactions, higher investments and assets / payoffs sharing, in order to find new multi-stakeholders metrics for urban logistics sector sustainability.

Research should cover the development and integration of the following issues:

- Truly, innovative, sustainable and long lasting forms of **cooperation** (e.g. public-public, public-private, customer-customer, private-private and private-customer) for urban logistics services that are adequate to new market evolutions and trends;

- Truly, innovative, sustainable and long lasting **business models** for vehicles and fleet sharing and pooling, infrastructures and networks sharing;

- New **multi-actor assessment framework** able to evaluate safety, economic and financial sustainability, societal acceptance, operational efficiency, level of innovation, labour and environmental impacts. It will provide evidence of implications on business and society, regulatory/legal aspects, reliability, security, insurance aspects and ethical issues;

- New **governance models** and related marketplace rules of the game - affecting all stakeholders - enabling a win-win collaboration able to remove barriers and eliminate any possible conflicts and encouraging cross-sectorial cooperation among competing services while capitalising on underutilised assets. Development of profit sharing and compensation / incentives schemes

and tools to measure the effectiveness and sustainability of models. Governance models should also indicate priorities and accessibility conditions for sharing of public infrastructures;

- Business-led roadmaps ensuring a **seamless and significant market take up and roll out of collaborative meta-business models** in different frameworks, with measures and incentives (especially for early adopters) and including communication actions and stakeholder participation on the potential of business models to improve sustainability in order to foster the acceptance by stakeholders across Europe.

[EXPECTED IMPACTS]

- Increased sustainability of the overall supply chain including cost-efficiency, policy and aspects,
- Increased loading factors and operational efficiency,
- Reduction of lead time and congestion,
- Better asset management and infrastructures use,
- New jobs creation and better working conditions,
- Increased trust and higher level of investments,
- Resilient use of available financial resources,
- Increased customer satisfaction.

2.1.6. Impact of introducing automated services in a multimodal scenario

Automated driving is seen as one of the disruptive developments that could potentially overthrow the entire existing mobility system. A longer-term slow revolution, i.e. the full automation of road vehicles, shall substantially change our vision of urban mobility. Indeed the fully unattended operation of urban rail vehicles has already been achieved for many years, mainly thanks to Communication Based Train Control - CBTC systems, and still needs to be promoted and protected (with specific research studies and telecommunications priorities), but once introduced, full automated driving of road vehicles shall bring a complete transformation of urban mobility practices. When automation will be able to serve huge amounts of vehicles both for passengers and goods– with most if not all of them moved by renewable energy - new "public transport" travel paradigms will replace the current ones.

It is important we spell out that cities are striving to reduce the amount of cars in the city and therefore, replacing driven vehicles by automated vehicles will not solve the problems of congestion and deliver the goal of more liveable cities. Several studies have shown that the automation of cars could in fact lead to an increase in the number of km travelled if the increased operational capacity that automation may well deliver is not managed in a proper way. Conversely, automating certain collective transport services, such as public transport feeders and car-sharing, could extend the range of public transport and new mobility services to a greater proportion of the population, thereby providing better access to services and possibly reducing the need to actually own a car.

With regard to road safety, there is widespread acknowledgement that driver distraction is a main cause of road accidents. By automating some driving functions, it is claimed that this safety risk will be mitigated. In the case of partial automation, it remains to be clarified however what this means for road safety, especially for cyclists and pedestrians, whose accident numbers are increasing.

Key areas of research of automated vehicles are not the promising prospects that lay behind the planning horizon, but the transition period that is needed to realise these promises. From an urban mobility perspective especially, the complexity of the complete urban system raises new implementation questions. There is a dire need for more understanding of the wider impact of automation on travel behaviour, where automation can help cities deliver their transport policy objectives and what interventions should be taken.

Several key research topics can be identified within this area:

• Certain **vehicle safety systems related to specific urban use cases** need to be improved, e.g. vehicle to person communication in reduced speed areas, emergency management procedures in crowded or congested areas, mixed traffic environment, etc.;

• Understanding the **behaviour** of the vehicle-owner and acceptance of these systems, but also the changing mobility system, e.g. the uptake of car-sharing in combination with automation of vehicles, and the interaction and co-existence between driven and automated vehicles.

• The role of **public transport** need to be revised for an optimised complementarity in the future automation scenario;

• As far as automated driving would reduce the need for infrastructure and parking in city centres, new ways and more adaptive **city planning methods**, including re-evaluation methods of urban areas, need to be developed. Concepts are necessary that can deal with this uncertainty, whilst preparing the urban infrastructure for the rise of automated vehicles;

• The overall mobility system will change due to many innovations, **borders between public and private transport** may get diluted and vehicle ownership may be seen from a very different perspective:

> For public authorities to get a better grip on these developments, tools are required that allow decision makers to take well supported decisions;

> New transport organisations (public and private) and travel options will be required;

> Balance between private and public operations of automated vehicles to optimise traffic management and satisfaction of customers travel (multiple and varied) requirements;

> Research is needed on the potential of automated shared transport systems in terms of their feasibility (land use patterns and population density).

> Research is also needed on the use of infrastructure and public transport networks shared by automated vehicles in connected nodes;

• Automated travel experience: a new consideration and appreciation of value of travel time in automated vehicles will have to be developed;

- Better understanding of the necessary conditions to allow and promote the shared use of autonomous vehicles for both private and public purposes – with regard to the functional and physical characteristics of autonomous vehicles, hire location (on-street parked vehicles or in-traffic moving vehicles), payment rules (and possible integration in a whole set of public mobility services), vehicle on-time availability…

[EXPECTED IMPACTS]

- Targeting zero fatalities,
- Reducing congestion,
- Acceptance of automation for transport services in urban context,
- Optimised multimodal mobility for passengers and goods,
- New mobility solutions within automated vehicles encompass user, road, and running organizations (private and public).

MILESTONES

Societal trends	Research topics	Type of action	Milestone
Decarbonisation	Reduce the use of cars	Policy development	2020
	New assessment methods to evaluate the impacts of innovative policy measures on decarbonisation and pollutant emissions	RTD	2025
	Promote eco-driving and eco-routing by study to change drivers behaviour	Demo	2025
	Develop more efficient policy interventions by studying the current modal split and travelling characteristics	Policy development	2025
	Improve quality of vehicle fleet	Deployment & market introduction	2025
	Assessment of impacts of new technological changes (digital society, e-commerce) on GHG and pollutant emissions	RTD	2030
City dynamics	Understanding people's needs and expectations	RTD	2020
	Exploring the potential role of neighbourhood-based solutions and services	RTD	2020
	Promote 'active' and safe mobility	Demo	2025
	Investigating into transport systems for more efficient use of space and balancing temporal and spatial priorities between modes and land uses	RTD	2025
	Investigate into approaches to increase capacities of travel modes, focusing on public transit and intermodal options	RTD	2025
	Possibility of sharing uses of urban land: shared parking for different activities along day/week days (offices, shopping, sports)	Deployment and market introduction	2025
	New assessment methods to detect the re-urbanization, densification and shrinking processes	RTD	2025

	New disruptive technologies and land use measures to control urban sprawl or to reduce the speed of urban sprawl, including increasing attractiveness of existing urban area	Policy development	2030
	Investigate the actual efficiency benefits of smart solutions using ITS and big data and to what extent they can replace infrastructure development	RTD	2030
Diogital society	Possibility of delivery cooperation among different logistic companies to avoid multi-trips	Deployment and market introduction	2025
	Evaluation of impact of the e-commerce growth over logistics design aspects in urban planning and urban design	RTD	2025
	Understand the trends in e-commerce and provide initial ideas for solutions for the sustainable development of all urban supply systems	Policy development	2025
	Impact assessment on the decline of car ownership and emission reduction in relation to the implementation of MaaS	RTD	2025
	Understand user needs, expectation and study on their satisfaction degree of using certain MaaS	RTD	2025
	Study on the actual environment of e-commerce market. Detecting and predicting the further development of e-commerce and online shopping in Europe	RTD	2025
	Investigating the consumers' needs and expectations to e-commerce in relation to urban mobility as well as the behaviour of actors in retail, logistics and delivery be changed by e-commerce	RTD	2025
	Understand the dynamics behind e-commerce	RTD	2025
	New business models to address the challenges associated with future integrated urban mobility solutions	Deployment and market introduction	2030
	Researches the influences of e-commerce on urban shape and land use including the changing demand for retail space and logistics areas	RTD	2030
	Investigate the effects of e-commerce differ in growing urban areas (densification) and in shrinking and marginalized areas	RTD	2030
	Innovative digital mobility platform with the support of government as third parties	Deployment and market introduction	2030
	Developing integrated solutions using big data, involving close cooperation between public and private actors	RTD	2030
Sharing economy	Deploy shared mobility solutions as part of intermodal systems	Deployment and market introduction	2020
	Truly, innovative, sustainable and long lasting forms of cooperation for urban logistics services	RTD	2020
	Truly, innovative, sustainable and long lasting business models for vehicles and fleet sharing and pooling, infrastructures and networks sharing	RTD	2020
	New multi-actor assessment framework able to evaluate safety, economic and financial sustainability, societal acceptance, operational efficiency, level of innovation, labour and environmental impacts	RTD	2020
	New governance models and related marketplace rules of the game	Policy development	2020
	Business-led roadmaps ensuring a seamless and significant market take up and roll out of collaborative meta-business models in different frameworks with measures and incentives	RTD	2020

	Behavioural aspects need to be deeply studied and carefully tackled	RTD	2025
	Legislation has to be produced with the deployment of new regulatory frameworks	Policy development	2025
	New optimization and simulation tools should be provided	RTD	2025
	Collecting and producing information and providing it to the users in an adequate and timely way. Generating KPI for sharing mobility services in terms of sustainability	RTD	2025
	The articulation of the individual demands and expectations	RTD	2025
Automation	Understand and update the behaviour of the vehicle-owner and acceptance of these systems	RTD	2025
	Develop new ways and more adaptive city planning methods	Policy development	2025
	For public authorities to get a better grip on these developments different trends and challenges need to be connected, identifying no-regret measures to allow for decision makers to make well supported decisions	Policy development	2025
	New consideration of value of travel time in automated vehicles	RTD	2025
	Impact of overall mobility system innovations on borders between public and private transport	RTD	2030
	New transport organizations (public and private) and travel options shall be necessary	Deployment and market introduction	2030
	Balance between private and public operations of automated vehicles to optimise traffic management and satisfaction of customers travel (multiple and varied) requirements	Deployment and market introduction	2030
	Research about the potential of automated shared transport systems in terms of their feasibility (land use patterns and population density)	RTD	2030

Table 1: Changing societal trends - milestones

2.2. Frameworks/Enablers

A number of frameworks, mechanisms and enablers can help to shape, facilitate and optimise the urban mobility system with a view towards reduced congestion, increased use of public transport and active travel, improved safety, more efficient and lower impact city logistics, and cleaner and fewer vehicles. In addition, tomorrow's travel experience will be offered as a seamless intermodal tailored solution accommodating the needs of different user groups within the European population. For this purpose, an integrated research method is required, covering the whole process from data and tools utilisation, to regulation and impact assessment.

Key frameworks and enablers for urban mobility that have been identified and are addressed in this chapter include the guiding framework of Sustainable Urban Mobility Plans (SUMPs), as well as strengthening enablers such as governance, regulation and business models, transferability, capacity building and upscaling approaches, which can also be innovative in nature, be it not from a purely technological point of view.

At the same time, the vast amount of big data becoming increasingly available today opens up a completely new range of possibilities for more informed policy making, multimodal modelling and improved user-oriented mobility services.

2.2.1. SUMPs

A Sustainable Urban Mobility Plan (SUMP) aims to satisfy the mobility needs of people and businesses in cities and their surroundings, while also aiming for a better quality of life and taking into account future demand and societal trends. Since 2009, the European Commission has recognised the importance of SUMPs in providing safe, green, efficient, equitable and integrated transport services and therefore launched an Action Plan to accelerate the take-up of SUMPs in Europe. Unlike traditional transport planning which mostly focuses on road traffic, SUMPs centre on and involve people, adopt a long-term strategic vision, and include a clear implementation and monitoring plan. It builds on existing planning practices and takes due consideration of integration, participation, and evaluation principles.

To develop and implement SUMPs, planners usually apply participatory approaches involving interdisciplinary planning teams with transport planners, urban designers, environment experts, as well as decision-makers, urban transport and mobility practitioners, citizens and other stakeholders. Better policy coordination and cooperation across different sectors is therefore essential. In order to be able to assess the impact of a SUMP, it sets measure targets derived from local or national objectives and adopts regular monitoring and evaluation activities to inform a structured learning and improvement process.

With newly emerging trends related to city dynamics, digitalisation, demographic change, automation, and sharing economy (see previous chapter), current SUMP methodologies and practices need to be adapted and enhanced in order to be able to meet related challenges. This requires comprehensive appraisal and evaluation of the urban mobility planning process and its trade-offs to increase competitiveness, social cohesion, environmental sustainability and health.

Further research should address the following issues:

• Consolidation of knowledge based on the **performance of existing tools**, including a review of good and bad practice;

• Research into the negative and positive **impacts of transport on economic activity**;

• Better understanding of the **link between transport and health**, in terms of road safety as well as physical inactivity and obesity, and air quality;

• **Appraisal, monitoring and evaluation approaches**, including simulation tools that provide scientific evidence to support policy options enabling urban economic development, improved public health and sustainable land use, and considering sharing-economy mobility services;

• Innovative tools for **stakeholder interaction**, strengthening the user perspective;

• SUMP optimisation in relation to **'macro' evolutions**: energy policy, fiscal policy, spatial planning, demography, cultural trends, new trends in retail, covering both the mobility of people and goods;

• **Holistic measures** integrating mobility management with automated vehicles, BRT and light rail, shared mobility services, hyperconnected vehicles (V2V, V2G and V2H), and land use management;

• How to properly incorporate **freight, electromobility** and other new policy fields into SUMPs.

- Establish and simulate the relationships between mobility plans and other sectors, for the mobility of both people and goods;
- Better governance fur urban mobility planning, based on a sound knowledge base, involving institutional and societal stakeholders;
- Evaluation methodology to compare planned and performed impacts at present and in the medium-long term;
- Integration of new mobility services into the planning process;
- New governance models that allows for a better coordination and integration between transport, land use, energy (including integration with Sustainable Energy Action Planning) and other key sectors.

2.2.2. Big data and modelling tools for better services and policy making

Decision makers (in both the private and public domain) need evidence in order to be able to make informed and documented decisions. Data provision is the first requirement for informed decision-making. Data serves as input for modelling mobility behaviour for different types of users and circumstances. Models then support the assessment of policy interventions in different temporal scenarios.

>> BIG DATA TRANSFORMATION TO ACCESSIBLE DATA <<

More and more available data sources produce "big data" in the urban domain. City authorities have embraced the 'accessible or open data' concept, but now the next step needs to be taken in order to make proper use of this data both by public and private parties. Benefits of big data to better services and policy making as well as modelling have not yet been fully exploited by transport professionals. Furthermore, new data sources (new sensors) are becoming available, allowing for improved monitoring of the existing situation to ultimately support the decision-making process. Part of these activities can be seen as building the smart city of the future, but this needs to be brought to real life, building on the demonstrators and pilots that have been running in the past years.

There are some trials on using big data for better planning (e.g. public transport route planning). However, there are many more opportunities for using location data and apps to provide better services, to make more informed decisions and to collect traffic data for modelling. For example, O-D matrix used to be collected through questionnaires and can now be obtained through location data of travellers or through a dedicated O-D data collection tool.

Yet, big data does not equal open data. The best-effort model has been used as a means to unlock data. The level of accuracy and latency of these data sources is now hampering the transport sector in developing appropriate business models based on these data sources. This needs to be solved in order to allow for good quality travel information and other services. Big data relates to the opportunities that arose with smart mobile devices, social networks and the interconnection of many devices and wearables, the latter known as the Internet of Things (IoT). In this area, different devices gather different types of data and are capable of processing and sharing these, either with other devices or through centralised systems. However, a careful investigation into the data and sound data processing is required before putting them to public use.

With regard to technical aspects, different existing and emerging sensors, channels and methods (Bluetooth, NFC, mobile phones, social media etc.) should be evaluated in terms of their capability to collect data that aid the monitoring and planning of traffic. The areas of possible applications include monitoring a city's daily traffic performance and transport demand and observing long-term changes in travel behaviour. In this context, algorithms are needed that differentiate between short-term and long-term changes in traffic flows.

Besides technical aspects, the quality of data is a key concern. A better understanding of the quality of data and a target-oriented matching of the data to the needs of urban and transport planners is needed. Accordingly, data fusion algorithms to join information collected from different sources need to be developed, as well as algorithms for deriving missing data from available ones. Data quality requirements by traffic management and traffic planning authorities need to be taken into account.

Topics proposed for research include:

- Better understand the **quality of data**, evaluate different channels of data collection and extract knowledge from big data for better services and policy making, e.g. by evaluating different sensors and methods (Bluetooth, NFC, mobile phones, social media, …) for their applicability to monitor a city's daily traffic performance and/or long-term changes in travel behaviour;
- Develop **new algorithms for data collection**, data expansion of the sample data to the total population and data fusion;
- **Best practice** collection and dissemination on using big data for planning and modelling;
- Guideline development on **using big data for transport service planning, evaluation and improvement**;
- Specification of **traffic data collection tools** of using smart phone (Apps) for various applications (e.g. O-D data collection) and other devices (IoT);
- Using big data to identify **flow of passengers** and use such results to identify needs of interchanges and designing interchanges;
- Integration of **operational, tactical and long-term** planning in order to be able to make better informed decisions, based on actual and real-time data;
- Connecting the different (ICT- and non-ICT) infrastructures to better allow for **operational optimisation**, whilst taking into account aspects like privacy and security;
- Develop guidelines (and policy) to data owners on **how to open data**.

>> MODELLING TOOLS FOR MULTI- AND INTERMODALITY <<

Models that compute the traffic demand, route choice and traffic flow for an investigated regional and urban territory include a modal-choice component, which usually determines a single mode used by the regarded person. With the growing interest in combining modes known as intermodality, the models need to be empowered to map intermodal trips, including non-motorised modes. Furthermore, new mobility options, such as car- or bike-sharing, and new technologies, such as pedelecs, need to be included in these transport models.

The use of new data sources (BigData), as described in the previous section, will facilitate input data for modelling with the necessary adaptations. Transport modelling tools would further benefit from the ability to combine transport modelling with evaluation tools. Thus, other aspects

of concern, such as cost, emissions, health and built structures may be linked to or integrated in future transport models.

The research challenges with regard to transport modelling tools relate to the following areas:

- Integrating mode and route choice approaches that take into account **multimodal and intermodal options**,
- New **sources of data to feed modelling** activities,
- Considering the **specific aspects of new mobility options** and technologies,
- **Quantifying the cost-benefits of using different modes** along a single journey,
- Improving the **modelling of energy use and emissions** through all modes in traffic models.

The successful development of modelling tools requires a strong linkage to research that improves the understanding of urban transport, for example of the opportunities and barriers for combining certain modes, generally and with respect to particular persons and areas. Models themselves may help in determining needs and barriers.

Research needs / aspects to consider:

- **Modelling mobility behaviour** for supporting optimised mobility management;
- Identification of **key influence factors** (so far only pure rational factors have been taken into account in taken into account at mobility demand models);
- Handling the complexity involved with models dealing with a high number of factors and high interdependencies between the factors, and in this regard developing methods to cope with **missing data**;
- Identification and specification of **data requirements** (rational vs. emotional decision making) and related acquisition technologies;
- Exploration of the potential to **transfer similar models** from other domains like macro-economic modelling of rebound and backfire effects, behavioural economics;
- Enriching map data to enable the application of **complex, intermodal mode and route choice** in the simulation;
- Extend **microscopic emissions modelling** to yet uncovered modes of transport (mainly rail-based), include electromobility into emissions modelling; improve the quality of microscopic models of vehicular dynamics for proper emissions computation;
- Efficient calibration of the simulation to guarantee accurate results for **decision support**.

>> IMPACT ASSESSMENT AND DECISION SUPPORT SYSTEM <<

Monitoring of progress regarding set policy targets and evaluating the contribution of different projects towards these goals is currently underdeveloped. In an increasingly complex environment where cooperation between stakeholders is key, the requirements for these impact assessments are changing as well. This however requires new business models to allow for benefits to be evenly distributed, but also access to different data sources.

Different data sources or big data enables a more detailed assessment of impacts of different mobility systems. Such data provides invaluable opportunities for transport planning, traffic management and travel information services. More data, however, also means that the systems that can process and analyse such data become increasingly complicated. Local authorities often lack the expertise to understand the significance and potential of big data.

Another challenge is that there is little use of new data sources for impact assessment and for evaluation of different measures in transport and mobility services. For example, to collect user feedback, traditional methods such as questionnaires and surveys are mostly used. Such information can be collected through social media in a more reliable and much cheaper way. However, many transport professionals may not be aware of such options and may not have the necessary expertise on how to exploit new data sources such as social media and smartphones for impact assessment. Therefore, there is a need for research on methods for impact assessment using different data sources and new media, in order to provide guidelines and best practices. Such research should also look into the possibility of evaluating future projects and public procurement.

Data privacy may also be barrier to be analysed. In terms of privacy, a balance has to be found between the protection of the individual's privacy and the usefulness of private data for the greater good of society.

Impact assessment and decision making can be democratised through participatory sensing. It is however not yet clear, how such data can be integrated with more traditional impact assessment methods (CBA and/or MCA) and to what extent we can rely on the credibility and representativeness of such data.

Policy makers have to be provided with user-friendly tools to manage the vast amount of data that is used for monitoring and impact evaluation. Meaningful and accurate visualisations, indicators and data dashboards are needed to bridge the gap between the increasing amount of data and its usefulness to society. Big data and participatory sensing provide new ways to segment impact assessment based on the different characteristics of users and society. It can also enable instantaneous assessment of impact through indicators.

Topics proposed for research include:

- Feasibility study of using **social media for evaluation of transport services** (e.g. traveller flows and demand, congestion, etc.);

- Proposing new Key **Performance Indicators** (KPI) for quality of transport and mobility services based on new data sources and social media;

- **Methodology on how** to use new data sources and social media for impact assessment and evidence gathering on transport and mobility services;

- Guidelines on **engaging users through social media** for proposing new mobility services and to evaluate project proposals and select public procurements;

- Study on the **impact of transport interventions for different segments of users** and the society through censoring and mobile data;

- New **multi-actor assessment framework** integrating safety, economic and financial sustainability, societal acceptance, operational efficiency, level of innovation, labour and environmental impacts.

Big data analytics will offer greater opportunities to link freight operators' with city planners' decision making (e.g. urban network planning) in order to achieve both a resilient, optimised, sustainable and cost-effective governance of the city and a more competitive context for business actors.

The following research aspects have to be addressed:

• Structured knowledge base on current **applications of Big Data** in urban freight transport;

• Analysis of **use cases** at different scales and for different market purposes (private and public) in terms of connectivity, procurement, pooling of assets, vehicles and fleet management, etc. These should have a positive impact (e.g. socio-economic, congestion, environment). Different data sources have to be identified, such as vehicles / fleets, private cars, open data platforms, crowdsourcing, social networks, etc. When looking at motivations to share the data and incentive schemes, new possible collaborative models could be investigated (e.g. PPP) including which market opportunities to match (e.g. sharing economy, e-commerce, circular economy – i.e. waste management and recycling). This will provide evidence on main barriers, prospects and emerging requirements for resource-effective use of Big Data in urban freight;

• Roadmap for wide-scale deployment of R&I solutions for **integrated knowledge and adoption of Big Data management in urban freight**. They will be pathways towards a "New generation" of Big Data management (intended as new business models on how to adopt freight Big Data not in silos). They need to improve: 1) freight demand management and overall efficiency of the sustainable urban transport system (networks capacity, vehicles/ fleets optimisation); 2) value creation of companies' assets and new business opportunities generated by better decisions as lever for increasing competitive advantage; and 3) regulatory frameworks facilitating economies of scale in procurement and accessibility to big data at lower cost and time.

[EXPECTED IMPACTS]

• Guidelines for traffic management and traffic planning authorities that describe how big data can be used for short- and long-term planning, for monitoring and evaluating policy measures and transport services. Within these decision support tools improved algorithms are necessary in order to better work with new data sources, improve quality of data, but also allow for better predictive capabilities;

• New reliable algorithms for impact assessment;

• Innovative decision-making system via Big data analysis;

• New and expanded traffic demand models and planning tools, as well as guidance for their application. Their integration with other tools will support evaluating intermodality with regard to social, economic and environmental aspects;

• Visualisation tools to help decision-making and public participation;

- New assessment methods incorporating participatory sensing;
- Better use of predictive analysis to achieve economies of scale in accessing data (accessibility of public sector to private data - lower cost than 20% - 30% and lower time);
- Faster development of big data programme and regulation frameworks in public sector and reduced procurement time frame for the use of private big data;
- Resilient use of city transport network (optimal network capacity with increased use of 15-20%);
- For freight, to engage with the public sector to profit from potential collaboration / dialogue with private sector.

2.2.3. Governance, regulation and business models

Governance and regulation are key issues for the planning, design, and implementation of transport policies. In particular, more and more integrated policy solutions are developed and applied through cooperation between private and public stakeholders, public participation, and special regulation.

For example, ITS and especially big data, provide increasingly robust decision making tools for urban transport. To manage the data collection and analysis, very specific ICT expertise is required which is often provided by commercial actors as local governments may lack the expertise. Many data sources and local mobility data are also controlled by commercial players. This can lead to conflicts between public and private interests. Increased collection of data from individuals (e.g. through smartphones) makes privacy an important issue.

Social media and online participatory tools enable a broader participation of citizens and other stakeholders in planning and decision making. The vast amount of feedback, however, poses challenges in terms of managing the participation process.

Governance in relation to new societal trends like sharing-economy and the use of disruptive technologies require new business models and a more prompt adaptation of policies and regulations in order to avoid conflicts.

Integrated transport planning and development is still hampered by conflicts between the different levels of governance and stakeholders with diverse objectives. While technology could already provide a full integration of information, ticketing, traffic management, local or regional governance structures often prevent such developments.

Therefore, challenges on governance, cooperation and regulation are affecting the emergence and sustainability of new business models both for passenger and freight transport. Funding schemes are deemed to be successful (or not), depending on the business model that generates them as well as the related stakeholders and policy contexts.

European cities are growing, and the dynamics of transport services have led to an increasing interest for sharing assets towards cost-effective and sustainable mobility and logistics processes in urban areas. Consumers and other stakeholders are showing a strong interest in the sharing-based economy. Re-thinking the value of "ownership" and favouring the one of "use" is the new disruption. However, there is still a need to find innovative ways to exploit new peer-to-peer businesses and their market potential, making them attractive and accepted (e.g. gamification). This means reinforcing reliability, trust in transactions, investments and assets / payoffs sharing,

in order to find new concepts of sustainability. Moreover, there is the need for a thorough understanding and a consolidated conceptual, policy and legal framework to properly focus urban interventions at different scales to maximise positive impacts and enable new business embedded into the entire urban ecosystem.

Mobility policies should first address people – serving their short/medium/long-term needs with appropriate infrastructure and services, and second, vehicles and related equipment – running/ parking road vehicles (including logistics management) and multimodal public transport.

Research should cover the development and integration of the following issues:

- Combine **flexible regulatory frameworks** and education of the citizens and stakeholders in order to protect individuals' privacy and the usefulness of private data for the good of society;
- Adapt **regulations in real time** using ITS and mobile technologies;
- New means to involve citizens in the planning process through online and offline co-creation and monitoring of impacts of mobility measures through **participatory sensing**;
- New methods to deal with **complex multi-level governance structures** that favour the better integration of (1) transport and land use, (2) mixed traffic in the city where PT is the backbone of the system, (3) energy and security issues, and identify the stakeholders involved;
- Develop **innovative forms of cooperation** (public-public, public-private, customer-customer, private-private and private-customer);
- Generate evidence of **impact** on business and **society**, financing sustainability, regulatory aspects/legal, reliability, security, insurance aspects and ethical issues;
- Analyse the **impact on cost and financial sustainability of public and private infrastructures**. Definition on priorities and accessibility rules for the sharing of public infrastructures;
- New methodologies, tools and marketplace to support **collaborative contingency and continuity meta-business models**;
- **Appropriate governance models and marketplace rules** –involving all stakeholders– to remove barriers and encouraging cross-sectorial cooperation among competing services and capitalise all underutilized assets;
- Regulatory and governance aspects of **integrating new mobility services**;
- **Funding and financing mechanisms** for urban mobility and logistics solutions considering mutual impacts (economic, environmental and social).

[EXPECTED IMPACTS]

- Goods delivery business models;
- Vertical and horizontal integration: high levels of cooperation, coordination and consultation between different levels of government and relevant authorities, developing bottom-up regulations;
- Automation regulation and integration;
- Funding & Financing mechanisms and business models.

2.2.4. Transferability, Capacity building and Upscaling

Methodologies for the mainstreaming, transferability and upscaling of innovative urban mobility solutions have been developed in EU funded projects such as NICHES+, TIDE, ZEEUS, ELIPTIC, EBSF(2), OPTICITIES, CIVITAS CAPITAL, ViajeoPLUS and SOLUTIONS (the latter two within the framework of international cooperation).

Due to different contexts and specificities of cities and countries, each with their own social and mobility challenges, policy objectives and user needs, such methodologies are crucial to allow for the successful transfer of good practice from one city to another, taking full account of key barriers, enablers and success factors.

Capacity building, knowledge transfer and site visits (i.e. to have first-hand experiences) are key measures that have been successfully applied in the aforementioned projects to upscale and transfer the best and most innovative urban mobility solutions. Making policy makers aware of best practices and solutions and handing them the tools to assess whether these solutions suit their own local context, often is the key to effective roll-out and implementation of promising innovations. However, such hands-on exchange and peer-to-peer transfer activities require accompanying support and capacity building for local practitioners and policy makers.

Focus of these actions should be on the creation of an innovation culture and establishing the right context conditions for innovation:

- **Political acceptance and support for innovation** can be a good driver since political power often is connected to many of the other frameworks that are important to break barriers and enhance deployment;

- **Public acceptance** of innovation is important, both in itself and in its close connection to political support;

- **Access to financial support** is another condition that can help in driving deployment. Financial support usually comes from politically initiated development funds or through direct political initiatives;

- **Coherence in legal frameworks** on all relevant levels is essential for some innovation measures. For others it is more a factor in enhancing the spread and deployment of the innovation;

- Access to '**best practice**' studies and guidelines directed at a specific innovation measure can enhance deployment of that innovation;

- Agreed **standards** between urban operators can expand the market for an innovation and provide security for investment;

- **Relationships between stakeholders on "the same level"** who share knowledge and experiences and/or cooperate to enhance deployment;

- **Relationships between stakeholders on "different levels"**, and, perhaps, with different interests, to increase the collective understanding of the innovative measure from their respective points of view, in order to enhance deployment through the right adaptations;

- Access to and protection of relevant **data** is a key condition for some of the innovative measures. Protection of relevant data can be seen both as an obstacle and a necessity in order to make it accessible;

- **Viable business models** are crucial for deployment of many innovative measures;

- With regards to research format, the **living labs approach** fostering open-innovation and testing a series of innovation options in real communities should be envisaged, as a basis for further knowledge transfer between cities;

- The further development and application of the TIDE **transferability methodology and 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.

Overall, Europe has been seen as the leader in sustainable transport and mobility. Some European cities, have reputations worldwide. Introducing their experiences to other cities would be beneficial. Till now, international cooperation with emerging markets often focuses on big cities. However, since European cities are comparably small, their experiences need to be properly considered if addressing different urban sizes, e.g. mega cities in emerging market countries. Therefore, the following areas may be worth further developing and studying in an international cooperation context.

- Optimise the practices of **mainstreaming, upscaling and transferring** good experiences in urban mobility contexts;

- International cooperation should be more but not only focused on **smaller cities** which often lack human resources, to optimise their productivity and results;

- Learning from **best practice of countries outside Europe**, e.g. emerging markets like China and Brazil, in order to strengthen the competiveness of European transport industry.

[EXPECTED IMPACTS]

- Guidelines for international cooperation in knowledge transfer and capacity building,

- Good practices of supporting uptake of innovative sustainable urban mobility solutions in Europe and beyond,

- Increased roll-out of urban mobility innovations in cities across Europe thanks to shortened innovation cycles and transferability tools for informed decision making.

MILESTONES

Enablers	Research topics	Type of action	Milestone
SUMPs	Study on how to properly incorporate freight and electromobility into SUMPs	RTD	2020
	Consolidation of knowledge based on the performance of existing tools. Research into the negative and positive impacts of transport on economic activity. Better understanding of the link between transport and health, in terms of road safety as well as physical inactivity and obesity, and air quality	RTD	2025
	SUMP optimisation in relation to 'macro' evolutions	RTD	2025
	Holistic measures integrating mobility management and land use management	RTD	2025
	Promote best practice exchange including sharing-economy mobility	Demo	2025
	Appraisal, monitoring and evaluation approaches, including simulation tools that provide scientific evidence	RTD	2030
	Innovative tools for stakeholder interaction, strengthening the user perspective	Deployment and market introduction	2030
Big data, modelling and impacts assessment	Identification of key influence factors	RTD	2020
	Structured knowledge base on current applications of Big Data in urban freight transport	Coordination	2020
	Analysis of use cases at different scales and market purposes (private and public)	Coordination	2020
	Roadmap for wide-scale deployment of R&I solutions for integrated knowledge and adoption of Big Data management in urban freight	Coordination	2020
	Better understand the quality of data, evaluate different channels of data collection and extract knowledge from big data for better services and policy making	RTD	2025
	Develop new algorithms for data collection, data expansion of the sample data to the total population and data fusion	RTD	2025
	Best practice collection and dissemination on using big data for planning and modelling	Demo	2025
	Using big data to identify flow of passengers and use such results to identify needs of interchanges and designing interchanges	RTD	2025
	Integration of operational, tactical and long-term planning based on actual and real-time data	RTD	2025
	Modelling mobility behaviour for supporting optimized mobility management	RTD	2025
	Handling the complexity involved at models dealing with a high number of factors and high interdependencies between the factors	RTD	2025
	Identification and specification of data requirements and the according acquisition technologies	RTD	2025

	Enriching map data to enable the application of complex, inter-modal mode and route choice in the simulation	RTD	2025
	Feasibility study of using social media for evaluation of transport services	RTD	2025
	Promoting new Key Performance Indicators (KPI) for quality of transport and mobility services based on new data sources and social media	Demo	2025
	Methodology on how to use new data sources and social media for impact assessment and evidence gathering on transport and mobility services	RTD	2025
	Study on the impact of transport interventions for different segments of users and the society through censoring and mobile data	RTD	2025
	New multi-actor assessment framework integrating safety, economic and financial sustainability, societal acceptance, operational efficiency, level of innovation, labour and environmental impacts	RTD	2025
	Guideline development on using big data for transport service planning, evaluation and improvement	Deployment and market introduction	2030
	Deployment of traffic data collection tools of using smart devices (Apps) for various applications (e.g. O-D data collection), wearable sand others (IoT)	Deployment and market introduction	2030
	Connecting the different infrastructures to better allow for operational optimization, whilst taking into account aspects like privacy and security	Policy development	2030
	Exploration of the potential to transfer similar models from other domains like macro-economic modelling of rebound and backfire effects, behavioural economics	Deployment and market introduction	2030
	Efficient calibration of the simulation to guarantee accurate results for decision support	RTD	2030
	Guidelines on engaging users through social media for proposing new mobility services and to evaluate project proposals and selecting public procurements	Deployment and market introduction	2030
Governance, regulation and business models	New means to involve citizens in the planning process through online and offline co-creation and monitoring of impacts of mobility measures through participatory sensing	Deployment and market introduction	2020
	Innovative forms of cooperation (public-public, public-private, customer-customer, private-private and private-customer)	Policy development	2020
	Regulatory and governance aspects of integrating new mobility services	Policy development	2020
	Combine flexible regulatory frameworks and education of the citizens and stakeholders in order to protect individuals' privacy and the usefulness of private data for the good of the society	Deployment and market introduction	2025
	New methods to deal with complex multi-level governance structures that favour the better integration of transport and land use and identify the stakeholders involved	RTD	2025
	Evidence impact on business and society, financing sustainability, regulatory aspects/legal, reliability, security, insurance aspects and ethical issues	RTD	2025

	Analyse the impact on cost and financial sustainability of public and private infrastructures	RTD	2025
	Funding and financing mechanisms for urban mobility and logistics solutions considering mutual impacts (economic, environmental and social)	RTD	2025
	Adapt regulations in real time using ITS and mobile technologies	Policy development	2030
	New methodologies, tools and market place to support collaborative contingency and continuity meta-business models	Deployment and market introduction	2030
	Appropriate bottom-up governance models and market place rules -involving all stakeholders- to remove barriers and encouraging cross-sectorial cooperation among competing services and capitalise all underutilized assets	Deployment and market introduction	2030
Transferability, capacity building and upscaling	International cooperation should be more but not only focused on smaller cities	Deployment and market introduction	2020
	Learning from non-European countries, such as emerging market countries like China and Brazil in order to strengthen the competiveness of European transport industry	Deployment and market introduction	2020
	Optimize the practices of mainstream, upscale and transfer of good experiences in urban mobility context	RTD	2025

Table 2: Frameworks/Enablers - milestones

2.3. Innovative urban mobility solutions and services

Innovative urban mobility solutions aim to improve transport services serving the needs of citizens within the current urban transport capacity constraints. In parallel to enhancing the integration of existing urban mobility networks, research efforts should also be geared towards the development and provision of new mobility services and adequate related transport infrastructure. These should cover both short and medium-term research actions targeting short to medium-term effects, and more long lasting research actions starting now to support policy decisions with long-term effects (e.g. driving the interaction between land use and transport).

The ultimate aim is to influence the behaviour of citizens in favour of sustainable transport modes and services and to support the optimised use of infrastructure in order to create an integrated sustainable urban mobility system that is able to meet the needs and expectations of citizens and society.

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

A. INFRASTRUCTURE-RELATED SOLUTIONS
B. MANAGEMENT-RELATED SOLUTIONS
C. SERVICES-RELATED SOLUTIONS
D. MODAL SOLUTIONS

A. INFRASTRUCTURE RELATED SOLUTIONS

2.3.1. Land use and transport interactions

>> CONTINUED EFFORTS TO UNDERSTAND THE INTERACTION BETWEEN LAND USE AND URBAN MOBILITY <<

Transport demand is intrinsically linked with land use and spatial structures. Urban planning and changes to the urban infrastructure are long-term measures, with a long-time planning horizon. There is a growing imbalance between expectations towards liveable urban space and the ever-increasing demand for mobility. Improvements to liveability often require a limitation of motorised traffic and new forms of freight distribution. This may lead to conflicts between urban land use/design and mobility planning. It is therefore important to better understand land-use and transport interactions in order to provide evidence-based knowledge for long-term urban planning.

Several trends have the potential to alter the way people organise their daily lives. Digitalisation, energy transition and more flexibility are some of those trends already visible (see also chapter 2.1). Digitalisation and cleaner, less air- and noise polluting production provide new opportunities to increase the mix and densities of residential and production-oriented land uses. Renewable energies, new technologies and flexible mobility concepts offer options for sustainably integrated production and consumption patterns. Changing commercial and logistics patterns, new distribution and business models may alter the access for the population to goods and services. However, we still do not know what the impact of these changes will be on land use and travel patterns. New mobility concepts, multi- and intermodality, automated shared vehicles will have an impact on land use patterns, since it is expected that the need for space devoted to transport infrastructure will shrink (less parking). On the other hand, new types of infrastructure will have to be fit into the urban fabric (such as depots and charging stations for automated electric shared vehicles, interchanges with public transport). Researching the interrelationships between land-use and transport thus represents one key aspect to improve long-term urban planning.

Concrete research priorities include:

• Developing and designing **land-use mix and zoning schemes** that foster flexible production and consumption as well as sustainable mobility patterns. More research is needed to investigate how new forms of mobility (both personal and freight) change the choice of residential and commercial locations and how these choices influence travel behaviour;

• Rethinking the **functionality of urban areas** and neighbourhoods to improve access to goods and services and to promote a vibrant cultural life;

• Conceptualising and analysing **urban nodes** that both support effective land use and a multi-modal and intermodal mobility behaviour ('places to be' and 'places to pass through');

• Investigating **new spatial logistic patterns** and their relation to equity of access;

• Providing **modelling tools and planning instruments** that integrate land-use and mobility interactions. Special attention should be paid to the impact of significant technological changes such as automated shared vehicles. These changes have to be incorporated into strategic regional or metropolitan land use –transport models;

• The impacts of land use changes are rarely seen in the short term, and politicians do not have ownership of the outcomes. Further research needs to clarify the **transport impacts of a wide range of land use decisions**, for example in terms of densities, location and population levels.

>> LAND USE AND TRANSPORT INTERACTION AT THE NEIGHBOURHOOD LEVEL: LINKING NEEDS OF PLACE WITH NEEDS OF MOBILITY <<

Securing the development and re-development of large sites and neighbourhoods within cities has traditionally relied on transport investment as a stimulus. This has led to transport and parking capacity enhancements in a relatively undiscriminating fashion, predominantly road based. In turn, this has created many unattractive and unfriendly environments, either because of new road-based infrastructure of a scale and appearance which detracts from the urban environment, or simply from increased traffic intrusion.

Environments of this sort are popularly disliked and have become quickly neglected, thus undermining the development they first supported. Many cities have taken steps to improve such areas – for example through pedestrianisation schemes. However, all such changes have encountered resistance on the grounds of economic and development detriment. More recently, evidence has started to come to light that improving the quality of urban spaces is now at least as important as access requirements to stimulate development. These findings from the development industry indicate that a good quality urban environment is a requirement for new development in cities. This has combined with popular feelings to produce approaches to traffic management which have (in some cases significantly) reduced traffic capacity in order to stimulate economic development. At the same time, though, overall access needs (by all modes) continue to need to be met to provide the economic base for any new development.

The research questions to be addressed in this regard are:

• To what extent has the need to improve the **urban environment** increased **relative to access requirements** as a basis for stimulating new development?

• Does this vary significantly between different parts of cities, different **categories of neighbourhoods** (by land use type), and cities of **different sizes** or in different countries?

• Is there any evidence that measures which reduce traffic impact in development areas have impacted negatively on **economic activity**?

• Is overall access by any mode sufficient to meet developmental requirements, or are **specific modal access requirements** essential?

[EXPECTED IMPACTS]

Research should result in:

• New integrated planning models and planning guidelines,

• A better general insight into long-term planning strategies, where the value of land may evolve based on transport services,

- A clear understanding of the different typologies of cities and neighbourhoods in terms of environmental and cultural needs versus mobility needs and new developments,
- Collection of evidence regarding the link between traffic reduction measures and economic activity,
- Improved insight into multi-modal access requirements for new developments.

2.3.2. Smart Interchanges

As urban mobility is strongly and increasingly based on complex intermodal systems, urban mobility services clearly depend on modal interchanges. These interchanges can significantly enhance travelling quality, by providing higher levels of accessibility, comfort, safety, available and reliable information, shopping, and many other services. Previous European research (i.e. HERMES, NODES and CITY-HUB projects) identified the key functions of interchanges and developed tools and guidance for new or enhanced interchanges.

A number of gaps and barriers preventing an increased use of public transport and improved sustainable urban mobility were identified in different EU projects (for instance CIVITAS) that could be tackled through a better design and management of stations and of multimodal interchanges. An urban transport interchange links various transport modes for both people and goods, including long distance modes (long-distance coach, airplane, rail and ship).

It also provides an arena for the provision of new and additional services targeting the passenger waiting time gap part of the connection (business lounges, various facilities, commercial areas etc.), addressing specific traveller categories (foreigners, tourists, business travellers, persons with reduced mobility, families, groups…), facilitating access to the station and egress from it (hired vehicles, shared vehicles, etc…); and providing information services (especially in case of operating incidents disrupting transport services).

The interchange also increasingly needs advanced regulatory frameworks, facing the movement and control of passengers crossing international borders at the interchange (international air or rail travel to/from Schengen space or outside Schengen space) and the integration of different operators and services.

The research topics on interchanges that need to be addressed are explained below.

The ways citizens and travellers can get closer to public transport and use it in combination with other sustainable and "sharing" modes (cycling, car sharing, carpooling) should be looked at as part of **feasibility studies** for stations and especially major multimodal interchanges between long distance and local travel, considering how they can best be integrated at urban nodes and activity hubs. Special attention should be given to the **physical design of stations and of interchanges** taking into account:

- **Land use and transport planning objectives** at various territorial levels (depending on the function of the station/interchange);

- **Layout constraints**: physical integration of the interchange in the surrounding urban fabric, allowing for high quality public space in and around the interchange structure;

- **Operational constraints** (at various periods of time) of the various transportation modes connected at the station (public transport lines and access/egress modes to/from the station/interchange), both in normal operating conditions and in degraded operating conditions; relevant requirements in terms of space needs and management (including garages and maintenance facilities);

- **Operational facilities**: access to sustainable and sharing modes, access to park & ride facilities for out-of-town interchanges;

- **Traffic forecasts** of the future traveller demand: number of passengers (per various categories of profile and purposes) entering or exiting the station/interchange; boarding/alighting the various public transport lines; transferring between the various lines and modes. For entering and exiting passengers, forecast regarding the access and egress modes used if not conventional public transport (taxi, park-and-ride, kiss-and-ride etc.);

- For international interchanges, areas and facilities needed for the **control of passengers** crossing international borders at the interchange (international air or rail travel to/from Schengen space or outside Schengen space);

- **Commercial and ancillary services** to be offered to the customers and visitors depending on the size and functions of the station/interchange (e.g. delivery of goods or parcels; laundry services; administrative services…);

- **Safety and security requirements** regarding the protection of staff and customers and the infrastructure and operational resilience in case of incidents;

- **Environmental impact** of the infrastructure and services provided;

- **Energy requirements and management** (including new EVs services power charging points for various categories of individual or public EVs);

- **Comfort requirements** for passengers, other customers and for staff (serving the station or serving on-board), including waiting areas, connecting facilities, booking offices, passenger information devices, luggage management, special passenger categories needs (e.g. PRM access), multi-use of interchange space;

- The **newest challenges** on urban mobility and interchanges, like increasing numbers of operators and services providers, security concerns, etc.;

- Possible **complementary use** of the station/interchange out of conventional use periods (e.g. for freight or goods delivery).

Further research on urban interchanges should enable the transition from "interchanges" to "Smart interchanges" by means of the following research topics:

- **Topology** of interchanges on the basis of scale, identifying the respective requirements and needs of each type of interchange and specifying their functionalities and characteristics, linked to the role of interchanges in networks and hierarchy of interchanges;

- **Integrated ticketing and travel information** for the various travel products delivered in relation with the station/interchange for a seamless travel experience;

- **New design** of infrastructures of interchanges in respect of:

> **Standardization of signage** at European level, multi-language signage targeted at foreign tourists,

> New installations and **security** issues,

> Innovative use of space within interchanges for **new mobility services** (e.g. retail, car/bicycle renting, parking, etc.);

• **Innovative services** at interchanges: integration of new services that respond to flexible demand and last mile with the use of intelligent transport systems to overcome silo approach of transport providers:

> Pilot and evaluate **new models for goods delivery** during the night-time;

> Practices to provide **integrated real-time information** (e.g. travel route, ticketing, alarm, etc.) via smart phone or other devices for all modes, including long-distance coach;

> Practices to provide **integrated ticketing** for the various travel products delivered in relation with the station/interchange;

> **Supporting services** (like passenger guidance by a trip tracker or assistance for persons with reduced mobility) to connecting travellers from a point of arrival of a given transportation mode to the point of departure of the next transportation service;

> **Multi-modal seamless transport management**, by exchanging information between mobility services providers in order to guarantee connections in real-time to transferring passengers (information exchanged between modes like a feeder bus system and rail stations). New IT tools now allow also to organise an appointment between individuals and new mobility providers ("on-demand" services, car-sharing, on-street EVs hire, bike hiring and other new services);

• **Assessment and evaluation** of interchanges that were designed and operated on the basis of previous research (NODES, CITY-HUB) guidance and results;

• **Carbon footprint** of urban interchanges and measures for resilient operations;

• **New business models** and governance and new investment funding and financing tools for (the design and) operation of stations/interchanges.

Research conducted in this regard could specifically focus on EU supported investment on interchanges and TEN-T urban nodes (EFSI, CEF, ESF).

[EXPECTED IMPACTS]

Research should result in:

• A topology of interchanges specifying different functionalities, characteristics and roles,

• New design guidance for interchanges infrastructures,

• Deployment of new services at interchanges,

• Better integration of ticketing services through smart devices: a truly seamless travel experience;

• Assessment tools and business models.

2.3.3. Optimised use of infrastructures

>> SHARED USE OF INFRASTRUCTURES <<

There are many barriers to expanding existing infrastructure or financing new infrastructure. Therefore, ways need to be found to optimise existing infrastructure and its efficient use. At the same time, the focus in urban areas is changing: from fluidity of traffic to a more place-led planning, with emphasis on the quality of urban space. Where more space is allocated to public transport or active travel modes, and overall available urban space stays the same, it is inevitable there is less capacity for passenger cars and for road freight transport. Consequently, separate infrastructure exclusively for cars and trucks tends to be reduced in favour of shared infrastructure.

Shared infrastructure brings up many research questions that need to be studied, like:

• What is the **impact of bus lanes** being **shared with other modes** of transport (bicycles, e-bikes, powered two wheelers, trucks, green cars ….), in the field of safety and service of public transport?

• To what extent can existing infrastructure have comprehensive **temporary regulations** (e.g. parking lane during a part of the day and for public transport the rest of the day; permission to use hard shoulders during rush hours; dynamic road for directing the available capacity according to place and time; ….)?

• How acceptable is assigning **privileges to some types of road users** (e.g. car sharing companies)? In addition, what facilities in terms of infrastructure use are needed to make new mobility services viable?

• How to **monitor, control and enforce** the right use of the shared infrastructure?

• What are **optimised strategies for shared infrastructure** in situations where road pricing systems are in place?

• In what way can **last mile logistics** take advantage of shared infrastructures – being it linear infrastructures or hubs? How to link consolidation and transfer points?

• What is the **impact of automation** on infrastructure and how to cope with that in the safest way?

>> CONTINUITY OF USE: RESILIENT INFRASTRUCTURES AND SYSTEMS <<

Road construction and maintenance for existing roads always have negative effects. Asset management tools to support decision-making by road authorities with respect to maintenance strategies and reserving funds for conservation of the road networks need to be implemented. Strategies to minimise the effective and perceived impact, as well as communication strategies, are an essential part in optimised use of infrastructure.

Quality of urban space and urban living is at the centre of almost all cities' attention. Nevertheless, solutions need to be found to reduce congestion. On the one hand, changing the structure of cities and improving car alternatives (public transport, cycling…) are possible measures. On the other hand, ITS and ICT technologies have a large potential for improving the efficiency of passenger and freight transport. Research on the implementation and assessment of new dynamic traffic management and infrastructure technologies remains needed.

With the improved flexibility of the transport system in terms of using different means of transport and increased ICT-usage, the consequences of disruptions on the network, both of a physical nature, e.g. road works, and ICT-related, e.g. cyber-attacks, can be large and impact on all travellers. Such disturbances will continue to occur, and their impact will only increase, not just with regard to predictable disruptions such as road works, but also regarding unpredictable events such as extreme weather conditions or terrorism. Besides its physical infrastructure, the current transport system also increasingly relies on a digital backbone and the related connectivity required. A new category of disturbances is therefore likely to occur with an increasing impact.

Europe is facing a changing security situation, and a new security culture is emerging. Big security threats seem to be well covered through existing projects, while the daily management of security threats is not yet properly addressed, including emergency interventions and the impact of overall raised security levels on transport systems and infrastructures. Passenger-friendly security systems are of great importance to keep PT attractive in such conditions.

With regards to resilience of infrastructures, the focus of research should be on:

- **Assessment methods** for the resilience of the transport system for both physical and digital disturbances;
- Management of **exceptional situations** (accident, traffic interruption, service disruption of any case) and measures to prevent and quickly respond to disturbances, including cost efficiency and an increase in recovery speed of systems and network;
- **Case studies** (at micro or macro level, depending on the nature of the incident) where analysis should be made in general and in each specific location/situation/city on the way to properly use social networks for collecting information or delivering information to passengers.

[EXPECTED IMPACTS]

Research should result in:

- Insights into the optimal use and impact of shared infrastructures, including regulatory aspects, acceptability, monitoring and enforcement,
- Guidance on how last mile logistics can take advantage of shared infrastructures,
- Assessment methods for transport systems resilience,
- Incident management strategies and case studies.

Solutions	Research topics	Type of action	Milestone
Land use and transport interactions – metropolitan level	Conceptualising and analysing urban nodes	RTD	2020
	Providing modelling tools and planning instruments that integrate land-use and mobility interactions	RTD	2020
	Developing and designing land-use mix and zoning schemes	Demo	2025
	Investigating new spatial logistic patterns and their relation to equity of access	RTD	2025
	Rethinking the functionality of urban areas and neighbourhoods to improve access to goods and services and to promote a vibrant cultural life	Demo	2030
Land use and transport interactions – neighbourhood level	The relation between the need to improve the urban environment and access requirements as a basis for stimulating new development? (with modal access requirements	Demo	2025
	The relation between reduced traffic impact in development areas and economic activity	RTD	2025
Interchanges	Topology of interchanges on the basis of scale	RTD	2020
	Carbon footprint of urban interchanges and measures for resilient operations	RTD	2020
	New design of infrastructures of interchanges in respect of standardization, security issues	Demo	2025
	Innovative services at interchanges	Deployment and market introduction	2025
	New business models and governance and new investment funding and operation financing tools for (the design and) operation of stations/interchanges	Deployment and market introduction	2025
	Assessment and evaluation of interchanges	RTD	2030
Optimised use of infrastructures – shared use	Impacts of shared infrastructure (Public/private transport) on safety and service levels	Demo	2025
	Efficiency and acceptability of (temporary) regulations related to shared use - including monitoring, control and enforcement of shared use	Demo	2025
	Impact/requirements of automation on urban infrastructures	RTD	2025
Optimised use of infrastructures – continuity of use	Assessment methods for the resilience of the transport system for both physical and digital disturbances	RTD	2020
	Management of exceptional situations (accident, traffic interruption, service disruption of any case) and measures to prevent and quickly respond to disturbances, including cost efficiency and an increase in recovery speed of systems and network	Demo	2025
	Case studies (at micro or macro level, depending on the nature of the incident) where analysis should be made in general and in each specific location/situation/city on the way to properly use social networks for collecting information or delivering information to passengers	Demo	2030

Table 3: Infrastructure related solutions – milestones

B. MANAGEMENT RELATED SOLUTIONS

2.3.4. Demand management

Demand management can be put into operation within several timeframes. Usually, a demand management objective is related to a real-time application (pricing, charging, etc.) that aims to reduce congestion, secure the seamless connection between two transport modes, or provide travellers with information, such as parking space availability or alternative travel options in case of an incident. Another application field relates to managing demand at the short to medium term, e.g. by updating traffic lights software or the timetable of public transport modes. Finally, from a longer term perspective, demand management can be defined as an approach with a view to designing and operating infrastructure and transportation services requiring huge investment and a long timeframe for design, approval and implementation. It is also a tool for better matching long-term land use policies with transportation planning (traffic forecasts and alternative analysis, feasibility studies, business case studies focusing on major infrastructure networks creation or development).

Innovation in research on demand management is expected to mainly influence the real-time and short-medium time objectives, by taking advantages of:

- modern IT tools allowing remote traffic management and surveillance (CCTV, traffic lights, parking occupancy);
- connected vehicles and travellers, able to be geo-located and to exchange information between themselves as well as with traffic management authorities.

Relevant research domains are mainly as follows:

- Behavioural response and public as well as political **acceptability** of access regulations;
- **Hybrid schemes** (e.g. interaction between measures such as Low Emission Zones, urban road user charging, parking etc.) are in need of more fundamental/theoretical research;
- **Context dependency**: how measures (like pricing, for instance) work in different local and regional contexts and how context dependent the impact of a measure is;
- Better understanding of the **behavioural response to parking pricing**, as well as getting to know the different components of the parking industry itself and how it works today;
- New **technology possibilities** make it interesting to evaluate cordon based pricing vs distance-based pricing, the latter of which is lacking in knowledge in the urban context;
- **Large scale pilots** are preferred when studying behavioural effects, in order to actually see the effects;
- Study the **interaction between policy measures**, how they work together, in order to understand the effects and formation of policy packages;
- **Multidisciplinary research** that combines understanding of ITS (charging technology), traffic engineering (network effects), micro-economic theory (consumer behaviour and welfare), psychology (attitudes), sociology (acceptance) and political science (decision making) is needed;

- Broad co-operation to ensure new knowledge in **multidisciplinary** manners, but with limited number of partners to achieve more efficient use of funds/resources;

- **Traffic and parking management, by providing:**

  > **on-street real-time information** about the level of traffic congestion and opportunities to use public transport and off-street parking near-by with information about availability of parking places and about public transport offer;

  > **in-parking information** about the location of free parking places;

  > **hands-off automatic toll or parking fee payment;**

- **Priority lanes** - or restricted streets - management, in places where priorities have to be given to certain categories of vehicles, and especially blue lights and public transport, over either the general traffic (e.g. bus lanes) or pedestrians (e.g. pedestrian areas). real-time management of such dedicated lanes or spaces could afford also some opportunities for urban logistics management at off-peak periods for goods delivery (Cf. Optimised use of infrastructures);

- **Public transport services management** (road or rail based: bus, tram, light rail, metro, suburban rail and new public mobility services like bike-sharing), by adjusting the supply offer to the level of demand either in real-time or later on by adjusting the timetable of the services. Real-time information is particularly useful in case of incident on regular services or during special large scale events;

- **Economic studies** based on the analysis of big data traffic characteristics for assessing the (neighbouring or city-wide) impact of various demand management policies on e.g. the environment (CO_2 and various pollutant emission, noise, vibrations), the energy consumption, the space consumption, travel safety and other external effects of travel (per mode) in order to improve the governance models and to adjust the demand management policies.

[EXPECTED IMPACTS]

Research should result in:

- Improved knowledge on the actual impact of different types of demand management measures in terms of local context, acceptability, behavioural change, interaction between measures;

- Large scale roll-out and assessment of TDM measures.

2.3.5. Integrated urban mobility and network management

Today, cities and regions still face challenges in effectively organising the coordination and management of different transport networks and operators in order to achieve optimal management of these networks. In this perspective, combined mobility is the key option for optimising the efficient use of infrastructures. This relates to the different spatial areas (urban/interurban), the different modes (rail, road, bus, traffic lights, freight delivery, etc.), and the different policy objectives and priorities (traffic efficiency, safety, environmental impact, etc.) to be covered, as well as to the different authorities and operators involved, and the different technical management systems and intelligent transport solutions being used.

Policy makers take decisions that should be implemented by the management level to allow for an increasingly flexible and multi-modal transport network. To this end, policy makers are in need of better information on the likely impacts of certain ITS measures on different policy goals (traffic efficiency, safety, environment, etc.) and of traffic management systems that are more responsive to policy. This would help to derive optimal operational guidelines for the coordinated management of the different networks, in order to achieve a given policy objective and answer the question when which measure needs to be put into action to actually realise the intended effect.

Innovative and coordinated transport network management should also optimise the travel experience of users in terms of accessibility, availability, reliability, comfort, safety, health, etc. This requires integrating active transport modes and new mobility services, making proper use of the increased amounts and types of data generated by connected travellers and vehicles, and using advanced demand and supply models.

For instance, efforts should address a better integrated network management approach addressing mixed traffic solutions, e.g. network and infrastructure design with a multimodal approach (public transport, electric cars, electric bikes, car-sharing, bike-sharing, ride-sharing, etc.) including parking and pedestrian areas; impact of (shared) autonomous vehicles on urban, suburban and regional public transport provision and design; AV impact on land use over time. Certainly, shared modes are excellent in complementing public transport for a door-to-door offer. Definitely, ride and car sharing work best where public transport is strong.

The OPTICITIES project has been looking into optimised urban mobility from the perspective of user needs, urban mobility policy, and business models of service providers.

Further research into the following topics is however required on:

- **Coordination approaches** that take into account all actors and stakeholders that perform, enable, advise or control urban, multi-modal transport network management;
- Practice of **incident and emergency management** addressing accidents/service suspensions and other major disruptions resulting from security threats, based on real-time data and enhancing resilience and fast recovery of the integrated network as a whole;
- The **traffic impacts of autonomous cars** with respect to network management;
- Updated **network management tools** to accommodate and manage both passenger and goods transport, also including environment and health considerations;

- **Data management and use**:

  > Integrating data collected both from private operators and public authorities to facilitate traffic management;

  > Making use of the vast array of data to support network management: define how to best use travel data provided before, during and after a trip (trip destination, crowdsourcing, social media, sensors, C-ITS probe vehicle data, big data approaches, …), while addressing issues such as legacy systems and required interfaces, new internal processes, advanced demand and supply models, real-time information;

  > New roles and approaches for local authorities in the open data environment: identify how to best provide infrastructure data for advanced services, defining the role of local authorities in the open data market and how to deliver data in an efficient and cost-effective manner;

- Developing **flexible infrastructure approaches**, including measures for optimisation (priority systems at traffic lights, dynamic dedication of road lines, parking space, …);

- Making systems development and implementation more **responsive to policy**, such as emissions-based traffic management or optimising people movement on surface transport, e.g. adaptive traffic control based on detection of vehicles, cyclists and pedestrians;

- Mapping the wide range of existing **decision support systems** and working towards their **integration** into a consolidated toolbox considering soft measures and irrational factors of human decision-making; work should build on the decision support system and KPIs developed by the CONDUITS project;

- Rethinking traditional **network control models and algorithms** which are now rather old and based on mechanistic approaches to traffic movements, including network management outside the traditionally controlled areas, based on the huge strides made in artificial intelligence, ubiquitous but incomplete information, ICT, etc.;

- Enhancing know-how and methods to ensure/encourage people's **compliance** with the intentions of certain measures and efficient impact assessment / quality assurance of the measures.

[EXPECTED IMPACTS]

Research will result in:

- Better coordinated network management to provide end users with more accessible and flexible and hence useful and reliable infrastructures and multi-modal services including information, integrated service provision, interchanges, ticketing, and parking;

- Methods and testing of these methods for the efficient allocation, preparation and exchange of data & information for and between users, network managers and policy makers, making use of existing and novel data sources;

- Strategies, processes and tools for informed policy decision making as well as KPI based realisation of the policy by transport network managers;

- Assessed impact of network management measures regarding transport efficiency, safety and environment, based on reliable compliance estimations.

2.3.6. Integrating urban mobility within overall European transport chains

>> CITIES AS URBAN NODES ON THE TEN-T: CREATING AN INNOVATIVE SERVICE ENVIRONMENT <<

Urban nodes pick up the TEN-T policy challenges on decarbonisation, air quality and congestion. The efficient and effective integration of urban nodes into TEN-T corridors requires further research and innovation efforts.

The TEN-T guidelines define urban nodes as urban areas where the transport infrastructure of the trans-European transport network such as ports including passenger terminals, airports, railway stations, logistic platforms and freight terminals located in and around an urban area is connected with other parts of that infrastructure and with the infrastructure for regional and local traffic.

In the guidelines, the EU recognises the functional role of urban nodes to enable the TEN-T to operate as a versatile and effective network. In this regard, urban infrastructures see an increased EU investment from CEF. These however, are mainly infrastructure-related investments (be it transport infrastructure, alternative fuel or ITS infrastructure). It is important that the urban nodes are also seen as territories where the inclusion of public transport schemes would help unleash their potential for the achievement of jobs and growth objectives within and between cities. This should enable the fast and seamless access of local and long distance travellers to the different means of transport located in major cities served by the corridors of the TEN-T core network.

As indicated in the TEN-T coordinators Issues paper published for the 2016 TEN-T Days conference, producing recommendations for the deployment of innovative solutions in urban areas can be very helpful for urban nodes establishment.

Research should focus on:

- The development of **KPIs** to measure the performance of urban networks and their contribution to TEN-T efficiency;
- Coordination and support actions, including expert networking activities, to further develop current practices and opportunities. These expert networking activities should focus on **how to deploy novel combinations of existing technologies/services in the urban nodes context**. The networks should also consider how to best involve new combinations of different stakeholder groupings - for example from research and innovation programmes, urban planners, infrastructure constructors/operators and investors - putting emphasis on creating synergies between results of HORIZON 2020 funded projects and CEF funding.

>> IMPROVING THE LINK BETWEEN URBAN AND LONG DISTANCE FREIGHT TRANSPORT SERVICES AND INFRASTRUCTURES <<

A major challenge to reduce freight transport movements and congestion and to increase the load factor in urban areas is the optimisation of the links between urban and long distance transport. This implies exploring new delivery models where connected hubs at different levels are shared by different retailers/suppliers to enter the city, and green vehicles are used for the last mile. A number of soft barriers including business models and collaboration need to be tackled to achieve a full realisation.

The following research areas need to be addressed:

• **Analytics models and tools** for urban planners to assess bottlenecks, existing infrastructures and constraints for optimal location and size of hubs, taking into consideration current and future flow demand, demography, etc. for different city segments and scenarios;

• Studies on **land use** and assessment of the impact of the multiplicity of logistics hubs and networks;

• **Pilot** solutions for optimising the use of Urban Consolidation Centres and micro platforms exploiting horizontal and vertical collaboration and supported by IT solutions enabling visibility of flow data for all actors with emphasis on the use of green vehicles for the last mile. Define measurement methods and KPIs to evaluate the performance of different solutions in terms of cost efficiency and environmental impacts;

• **Decision Support Tools** for appropriate types of vehicles, vehicle architectures, sizes and weights limits to optimise efficiency and sustainability depending on different cases and characteristics of city/district/area and logistics traffic;

• **New design concepts** for containers, boxes, modular units and handling solutions to ease transhipment operations between long distance and last mile legs;

• Pilot and evaluate different **business and governance models** by defining roles and responsibilities for all actors, rules for hubs, ownership of the services and interactions between actors;

• Measures for **public involvement and procurement** strategies.

[EXPECTED IMPACTS]

Research should result in:

• Tools to measure the performance or urban networks and their contribution to TEN-T efficiency;

• Improved stakeholder cooperation within an urban nodes context to create synergies between different activities and programmes and enhance the roll-out of new combinations of technologies and services in urban nodes;

• Increased use of assets and infrastructures by 30%;

• Reduction of congestion and CO_2 emissions by 30% through optimisation of traffic between hubs and urban areas, improvement of load factor and use of green vehicles.

Solutions	Research topics	Type of action	Milestone
Demand management	Behavioural response and acceptability of access regulations	Demo	2020
	Hybrid schemes (interaction LEZ, urban road user charge etc.) and policy packages	RTD	2020
	Behavioural response to parking pricing, understanding different components of the parking industry	RTD	2020
	Priority lanes and restricted streets management	Demo	2025
	Public transport services management to adjust supply and demand	Demo	2025
	Economic studies on impacts of demand management measures, as well as context dependency	RTD	2030
Integrated urban mobility and network management	Coordination approaches for multi-modal network management – responsive to policy	RTD	2020
	Map existing decision support systems and working towards their integration based on KPIs (CONDUITS)	RTD	2020
	Practice of incident and emergency management for resilience and fast recovery of the network	Demo	2025
	Traffic impacts of autonomous cars with respect to network management	RTD	2025
	Data management and use	Demo	2025
	Updated network management tools to manage passenger and goods transport, including environment and health considerations	Deployment and market introduction	2030
	Developing flexible infrastructure approaches, including measures for optimisation	Demo	2030
	Enhance knowhow and methods to encourage people's compliance with measures /impact assessment/ quality assurance	Demo	2030
Integrating urban mobility with overall European transport chains – cities as urban nodes on the TEN-T	CSA and expert networking activities to relate CEF funded urban nodes activities to the H2020 environment	RTD	2020
	KPIs to measure the performance of urban networks and their contribution to TEN-T efficiency	RTD	2025

Integrating urban mobility with overall European transport chains – urban and long distance freight	Analytics models and tools for urban planners	RTD	2020
	Pilot solutions for optimising the use of UCC and micro platforms	Demo	2025
	Decision support tools for appropriate vehicles, vehicle architecture, size and weight to optimise efficiency	RTD	2025
	New design concepts for containers, boxes and modular units	RTD	2025
	Pilot different business models and governance models for all actors	Demo	2025
	Measures for public involvement and procurement strategies	Deployment and market introduction	2025
	Studies on land use and assessment of the impact of logistics hubs and networks	RTD	2030

Table 4: Management-related solutions - milestones

C. SERVICE RELATED SOLUTIONS

2.3.7. Integrated information

Available massive data and the sprawl of information have an enormous potential for the development of new services and for supporting better decision-making at all levels (from the multi-modal traveller to systems managers or policy-makers).

So far, information services have mainly focused on travel time, departure and arrival times, as well as pricing. However, for private decision-making, especially with regard to active modes of transport, many more aspects play a role when it comes to choosing routes and modes. Access to information about travel options and services is vital and functions as personal assistance. Typical examples of additional decisive parameters are information on safety and security along the route, comfort, cleanliness of vehicles, attractiveness of a route in terms of noise levels, passengers' footprint, and mode specific facilities that help to reduce the number of dangerous interactions with other modes of transport. A lack of such information can dramatically reduce the chance of changing mobility habits in favour of more sustainable modes. Furthermore, such information is also well-suited to make people more aware of their actual travel impact (even beyond the carbon footprint).

With massive market update of smartphones and social networks, people have also changed their way of seeking information. Social networks and apps providing customised information have led to increased shares of these channels. Market shares of government funded integrated information services have decreased, while private services (mainly through apps) have started to become predominant.

Integrating information services would bring huge benefits to travellers when combined with electronic payment facilities and real-time travel information through smart phones, positioning

(GPS) and ubiquitous mobile broadband. The market is already providing innovative products that citizens want and need and the European Commission should therefore focus on creating the right environment to allow this market to flourish. The role of data brokers and digital service providers is and will be a continued point of attention.

Mobility as a Service (MaaS) refers to combining all forms of personal transport together into seamless trip chains with information, planning, booking and payments managed collectively for all legs of the trip. To enable market growth and development through these new concepts, transport data needs to be made available to allow third parties to bring together information from a variety of sources and build these services for users. Research has shown that transport operators are willing to open their data but often lack resources and technical capability to do so. The European Commission should continue to support and encourage open data policy and similar solutions to ensure that all transport operators, regardless of their size, are able to open their data with adequate technical support and without additional financial burden. This will also decrease the time-to-market implementation of new IT solutions.

Key topics for research are:

• **Quality** of data and validation of information;

• Identification of **information gaps** and determining parameters, and how these factors can be measured efficiently (including the question on if a local authority should even collect such information and data and make them available from an ethical point of view), and the expected effect of such information on travel behaviour and modal shift;

• **Multi-disciplinary research** for the design and deployment of information systems for intermodal traveling and interchanges (maps, signs, timetables, information on the web, mobile phones, etc.);

• Research on providing **customised information** to travellers with reduced mobility (not only disabled but also older people): experiences show that apps are used by older people as well. However, different from apps for standard traveller information services, such apps may not have much commercial value due to limited market shares. Research into how to incorporate specific user needs and develop integrated services for travellers with reduced mobility or with other special needs (e.g. older people) would fill the gap of the current market;

• **New real-time information systems** - related to hyper-connected travellers - addressing public mobility travellers needs:

  > Development of traffic forecasts of the future travellers demand and flow based on big data: number of passengers entering or exiting the station/interchange; boarding/alighting the various public transport lines; transferring between the various lines and modes. For entering and exiting passengers, forecast regarding the access and egress modes used if not conventional public transport (taxi, park-and-ride, kiss-and-ride etc.);

  > Before travel (travel query, travel products booking and payment, changing requests);

  > During travel (including along the connection path between two transport modes for transferring passengers);

  > After a travel incident (service delay or disruption) has occurred (re-routing, contact points, assistance services);

  > Injured passenger's assistance – e.g. health profile on the smartphone; assistance in case of trauma; information of passenger relatives; information of the public through social media...).

>> STANDARDISATION OF DATA FORMATS AND CONNECTED SERVICES <<

The uptake of connected mobility services is linked to the quality and the availability of reliable data for its technologies and its users. This also comprises data migration capability when a user moves from one provider (e.g. city) to another. Full interoperability among the systems of multiple players is a key requirement for better services.

A lot of work has already been done towards the standardisation of data formats, but higher levels of system interoperability are clearly needed, and integrated approaches have to be developed, which can only be done through new forms of inter-disciplinary research. Further research is needed, preparing for standardisation, not only in terms of data formats and semantic consistency, but also on the interfaces through which data is transformed and manipulated.

Research topics to be addressed:

• Data formats must be standardised with regard to their **communication protocol** as well as its **storage** (database) format. Development of standard platforms for collecting data and new forms of data and systems integration are required. Each data set should ideally contain information about its acquisition method and accuracy to enable safety-related services for (vulnerable) mobility users. The fact that "open data" poses additional difficulties in terms of integration should also be addressed;

• When personal data is massively collected, information **privacy issues** (as well as data ownership) become rather critical, thus deserving special attention;

• The **quality and performance** of advanced urban mobility information services are strongly affected by the data collected from and provided to individual travellers, through the massive recourse to mobile devices, strongly dependent on broad reliable network coverage. This is still a strong barrier in many contexts, requiring research for the development of sounder technological solutions;

• To be really effective, research needs to be strongly aligned with broader initiatives that go far beyond Europe and are of **worldwide scope**.

[EXPECTED IMPACTS]

• Identification of information gaps and requirements and development of new parameters to fill these gaps;

• Enhanced multimodal and real-time information services;

• Tailored integrated information services for mobility impaired people;

• Standards for data collection and integration, which will in turn facilitate frameworks for new business models and provide the basis for technology integrators of mobility innovations.
They will also contribute to cost effectiveness of technologies and services.

2.3.8. Integrated payment

The overall concept of "integrated ticketing" is not new for public transport: a lot of regions / cities have developed their own integrated ticketing systems and applications which include public transport modes and even the use of private modes (combination of parking and public transport services, combination of all public transport and on-street hired bikes or electric cars, etc.). Within a MaaS context, we can further expect a rising number of Transport and Digital Service Providers.

Many appropriate solutions developed at a local (and sometimes national) level are very successful. As far as local public transport is concerned, fare policies are an essential component of a transport policy targeting the application of public service requirements serving the general interest or specific communities (like persons with reduced mobility or low income households), and the responsibilities of the competent authorities in that regard should be kept untouched, even though fare integration should be encouraged between the various urban, suburban and regional public transport modes in order to facilitate their use. Therefore, future developments of integrated ticketing should always follow a bottom-up approach, taking into account the choices made by urban agglomerations. It is necessary to stick to allowing urban areas competent authorities to choose the ticketing system that best fits local circumstances.

At the local level, some political initiatives have also introduced toll systems as a traffic management tool for charging the use of private means in congested areas. Most often, on-street parking pricing is now extended in a majority of municipalities within important agglomerations (although scarcely in coordination at the overall conurbation level). Integrated payment thus is linked with the overall issue of fair pricing of the use of urban infrastructures (road use, parking, freight loading/unloading bays) and even with the use of other services (e.g. EV-battery charging).

At national level, many countries have introduced charging systems for the use of express ways or for the transport of goods by trucks. Some relevant initiatives have even been coordinated at European level (expressway gate through hand free payment). The growing complementarity of vehicle ID/licence plate based systems with personal payment systems (card or mobile phone) will also become more visible seamless payment systems in cities.

During the last years, many new transport services have also been emerging in relation with connected vehicles and customers (e.g. car sharing, on-street electric car hire…).

At the same time, an increasing number of local citizens is travelling out of their daily living area, and they have to be considered more and more by public authorities at all levels as European citizens with travel needs encompassing the whole European territory (Schengen area or not).

Therefore "integrated ticketing" is a concept which content is evolving rapidly, depending upon both the travel services and the travel areas which are covered by that "integrated" ticketing. And the "ticket" itself is also a notion which in many cases is no longer related to a materialised printed support but to tokens, with the development of EMV standard cards, NFC enabled devices and/or smartphones ticketing apps.

Based on this reality and the existing ticketing services, a series of recommendations for further research actions are proposed below:

- Research promoting and facilitating **cooperation between national and regional Smart Ticketing** schemes to establish interoperable "Smart Ticketing" in Europe. In particular (but not only), the following activities should be covered:

  > Encouraging the development, agreements and publication of the various **functional and technical requirements for smart ticketing interoperability**: travel information and ticketing of long distance trip needs to include the local (last mile) information and should build on the local requirements already available;

  > Pursuing the establishment of **trust schemes**, specifications and certification for seamless travel between schemes with different standards;

  > Cooperating with other European and international bodies to promote interoperability in Smart Ticketing;

  > Collecting and analysing the **legal background** and constraints for developing integrated ticketing across modes and between long distance/international travel and local travel in the same seamless trip;

  > Analysing the **sustainability** of integrated ticketing schemes for transport operators (especially SMEs), e.g. on how to guarantee sufficient cash-flow;

- Investigating how to facilitate the payment in the same query of **co-modal transport services** (separate payment of the different "tickets") and, later on, of **seamless multimodal travel products** (one payment for the whole set of transport or travel related products used from A to B and even at A and/or at B); seamless travel may encompass all types of public transport, by air, by rail, by road and waterborne;

- Investigating **new charging methods** based on real use addressing the whole mobility chain, thus including parking fees and others - hyperconnected vehicles (beneficiary pays principle)

- Supporting through research the development of relevant **CEN standards**;

- Extending functionalities to facilitate **intermodality** (seamless air-rail-coach travel including local public transport) and demand management. However, the air-rail integration gathers many more aspects than information and ticketing. It has to be based also on physical access (interchanges) and commercial agreements under the responsibilities of the parties involved which might be reflected in integrated ticketing schemes;

- Adding new **ancillary services** linked to the integrated e-ticketing to improve and enlarge the travel experience inside the means of transportation;

- Considering **services** which are not offered on-board transport vehicles or in stations but which are accessible through transport means within the cities visited (e.g. entrances to museums, to dwellings in Sky resorts; delivery of parcels in some stations…);

- Developing **new pilots** in more depth: converging long distance and the first and last mille ticketing: enlarging the regions and cities involved in new EU pilots;

- The provision of **combined ticketing schemes** is facilitating access to and simplifying the use of combined mobility solutions: car-sharing can be further encouraged by granting discounts on public transport subscriptions, etc. All the ways of incentivising citizens to get closer to public transport and other sustainable and "sharing" modes (cycling, car sharing, carpooling) have to be investigated and analysed by future research along with the best way for these mobility services to be integrated at urban nodes and activity hubs.

Research should result in:

- Enhanced cooperation between national and regional smart ticketing schemes with a view to establishing interoperable smart ticketing in Europe;
- Improved and easier one click payment schemes and booking for co-modal transport services;
- Contribution to the development of relevant CEN-standards;
- New ancillary services to be integrated in e-ticketing;
- Large-scale pilots implemented.

2.3.9. Urban freight and logistics solutions

>> BRINGING LOGISTICS INTO URBAN DESIGN <<

Today, a general transport infrastructure plan for both people and logistics is missing in city planning. It is necessary to define conditions towards proper consideration of urban logistics infrastructure needs and urban design aspects through Sustainable Urban Logistics Plans. The involvement of all key stakeholders, business actors, local administrations and local politicians, is crucial to achieve awareness and consensus on urban design decisions. Business models for building and operating facilities, how to get financial support and how to get greater efficiency in the management of infrastructure are the main challenges of this topic.

Key factors in developing approaches towards a better integration of city logistics into urban design include:

- **Involvement** of **all key stakeholders**: business actors, local administrations and citizens. Political representatives are particularly important to raise awareness and reach consensus on urban design topics; so far they have not been involved in city logistics projects;
- Design of the **infrastructure**, including the distribution nodes network and logistic platforms serving the city and business models to make the infrastructure economically sustainable. Design should be based on strategic scenarios modelling and visualisation, to demonstrate and test different scenarios and to help understand what is already being done well (best practices). Scenario evaluation criteria should include: use of infrastructure 24h a day, understanding total demand (in/outs), taking out what can be done outside the city, development of new infrastructure vs. use of existing infrastructure.

This translates into the following research priorities:

- Recommendations on **architectural design and integration of logistic facilities in urban areas**, as well as the business models supporting them. This means understanding how to best build and manage - in an optimal and resilient way - logistics city infrastructures (loading/unloading areas, consolidation centres, pick up points, warehouses, etc.) and urban design adequate to (evolving) dynamics of urban delivery services. This involves:
  > Research on use of brown fields for urban freight deliveries, or the architectural design and integration of logistic facilities in urban areas, as well as the business models supporting them;

> Research on the vertical exploitation of space for goods storage and transport;

> Development of an adequate tool for simulating impacts / benchmarking and set use cases;

> Good practices handbook for decision makers, to allow understanding what has already been done well, for different typologies of cities, as there are very different urban situations;

• Analytical **economic models** to support stakeholder analysis, balancing logistic efficiency and life quality;

• **Large-scale demonstrators** on logistics planning for urban city planners showing the impact of concepts, tools and innovations.

>> EXPLORING NEW OPPORTUNITIES FOR ACHIEVING EFFECTIVE INTEGRATION OF URBAN FREIGHT AND PERSONAL MOBILITY: SERVICES AND NETWORKS <<

Further exploitation of the potential of integrating urban freight and passenger transport systems will optimise the use of road, rail and inland waterways infrastructures in space and time, and contribute to healthier cities in terms of less traffic and congestion. This requires a change of paradigm towards a freight/passenger integrated mobility planning and exploring more opportunities and new business models for the integration of urban freight with private or public transport at infrastructure and vehicle levels.

Research topics to be addressed in this respect include:

• Tools to identify **opportunities of flows integration** and support the development of integrated mobility plans. These tools should:

> Identify potential network capacity and technological/non technological constraints/enablers to multipurpose use for freight and passengers;

> Adopt probabilistic models to match demand and supply;

> Identify new methods for data visualization for different types of traffic (e.g. services, goods, parcel, shopping trips);

> Find effective stakeholder engagement (multi-actor) approaches for accepted governance and mutual benefits;

> Design simulation tools to evaluate the potential of integration and prediction;

• **Evaluate different measures for freight and passenger integration** in terms of environmental and social impact, level of traffic decongestion achieved, job creation, economic impacts, through pilot testing in different types and sizes of cities. Legal, security, privacy, and societal aspects should also be evaluated. Measures should involve solutions at terminals or junction points between goods and people (e.g. lockers in metro or bus stations), links with neighbourhoods and districts, control / monitoring systems of urban spaces, etc.;

• **New concepts and technologies** in vehicle architecture, containers and logistics unit design, transhipment and handling technologies contributing to a better integration of flows;

• Define **resilient governance models** and incentives/enforcement systems;

• Development of **business models** offering mobility as a service (MaaS) to connect people and goods movements.

>> THE DATA CHALLENGE <<

To support urban logistics services, a wide range of technological solutions have been developed over the years. Yet, major barriers still persist to the exchange of information among the different actors and stakeholders, both of a technological and business nature. New forms of data and information sharing, along with the development of tools and incentives for collaboration are clearly required.

The following research priorities have been identified:

• Further explore how to **use automatically collected data** to analyse urban freight transport and its impact in cities. Despite multiple efforts to develop a framework for data collection, there still is little data available on urban freight transport. There are many reasons for that: unwillingness to share data by private actors, (local) policy makers who do not want to invest in collecting these data, difficulty to collect all data that are needed to come to a proper analysis, etc. At the same time, a lot of data is collected automatically (ANPR cameras, road charging systems, automatic traffic counts, etc.). Today, these data are not used to analyse urban freight transport. It would be interesting to further explore how that could be done;

• Develop a **framework for data sharing**: Private actors in urban freight transport and in logistics in general are not keen on sharing data because they are afraid of sharing sensitive information. They don't want their competitors to have access to these data. However, sharing data could lead to more sustainable urban freight transport. It would increase the options for consolidation and it would stimulate innovation (vehicle technology, ITS solutions, etc.);

• Develop tools to **analyse** all available **data** that can be linked to urban freight transport: Once steps have been taken concerning the two previous actions, there will be a need to develop new tools to analyse and use the available data. These tools can address local policy makers, private actors involved in the urban supply chains or researchers.

[EXPECTED IMPACTS]

• A better understanding of how to best build and manage city infrastructures (loading/unloading areas, consolidation centres, pick up points, warehouses, etc.) in a resilient way and adopt an urban design approach which is adequate to the (evolving) dynamics of urban delivery services;

• Good practice guidance for decision makers, to allow a better understanding of what has already been done well, addressing different typologies of cities;

• Increased use of assets and infrastructures by 15%;

• Reduction of congestion and CO_2 emissions by 20% through optimisation of traffic and better vehicle utilisation;

• Reduction of congestion and CO_2 emissions by 15% through use of public transport networks for freight deliveries.

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Solutions	Research topics	Type of action	Milestone
Integrated information	Quality of data and validation of information	RTD	2020
	Identification of information gaps and determining parameters (including ethical issues), expected effects on modal shift	RTD	2025
	Multi-disciplinary research for the design and deployment of information systems for intermodal travel	DEMO	2025
	Customised information for travellers with reduced mobility	Deployment and market introduction	2025
	New real-time information systems	Deployment and market introduction	2025
Integrated information – standardisation of data formats and connected services	Development of standard platforms for collecting data and new forms of data and systems integration	RTD	2020
	Information privacy issues and data ownership for massive collection of person data	RTD	2020
	Quality and performance of advanced urban mobility information services	RTD	2025
	Global cooperation on these topics	RTD	2025
Integrated information	Cooperation between national and regional smart ticketing schemes to establish interoperable smart ticketing	Demo	2020
	Payment in the same query of co-modal services and of multimodal travel products	Demo	2020
	Promotion of CEN standards	Deployment and market introduction	2025
	Extended functionalities for intermodality (long distance), demand management, incentives for shared modes	Demo	2025
	Investigating new charging methods based on real use addressing the whole mobility chain, thus including parking fees and others – hyperconnected vehicles (beneficiary pays principle)	Demo	2025
	Extended functionalities for ancillary services, and non-transport services	Demo	2025

Urban freight and logistics - urban design	Analytical economic models to support stakeholder analysis	RTD	2020
	Recommendations on architectural design and integration of logistic facilities in urban areas as well as the business models supporting them	Deployment and market introduction	2025
	Large-scale demostrations on logistics planning	Demo	2025
Urban freight and logistics – exploring new opportunities for integration of urban freight and personal mobility	Tools to identify opportunities for flows integration and support integrated mobility plans	RTD	2025
	New concepts and technologies in vehicle architecture, containers and logistics unit design	RTD	2025
	Resilient governance models, incentives and enforcement systems	RTD	2025
	Business models offering MaaS to connect people and goods movements	Demo	2025
	Social and environmental impact evaluation of integrated measures for freight and passengers	RTD	2030
Urban freight and logistics - the data challenge	Use of automatically collected tot to analyse urban freight transport	Demo	2020
	Data analysis tools that can be linked to urban freight	Deployment and market introduction	2020
	Framework for data sharing	Deployment and market introduction	2025

Table 5: Service-related solutions - milestones

D. MODAL SOLUTIONS

2.3.10. Clean fuels and vehicles

The combustion of fossil fuels, one of the key technologies of the transport sector, leads to an aggravation of local and global air quality as well as contributes to the increase of greenhouse gas emissions. Indeed, the path towards a guaranteed greener energy supply and consumption and an effective climate protection needs to be built at the hand of the transport sector. Moreover, the COP21 was clear when identifying public transport as a stepping stone to reduce emissions and to keep global average temperature increase below 2°C (Paris Agreement).

During the past years, many technological developments have proven to be mature enough to allow for the implementation of cleaner vehicles. However, research on new fuels – including new electricity production – is still useful, and for innovative solutions there are further stumbling blocks: from the silo perspective of different means of transportation to resilient outdated business models.

Some of the key research points that could accelerate the transition towards sustainable multimodal electro-mobility are the following:

>> MUTUALLY-SUPPORTIVE TECHNOLOGIES AND NEW WAYS OF USING THEM <<

The options for a lower carbon transport system are numerous, diverse and mutually-supportive. Therefore, for public transport a "clean fleet" can be composed of hybrid, electric and alternatively fuelled vehicles. In addition, new private means of transportation (electric car, electric bike…) offer new opportunities for a complementarity between private ownership/use and public transport. There is a need of properly analysing possible alternatives depending on the environment and conditions of each city. Operators and Organising Authorities can help proving new concepts through pilot or demonstration projects.

Technologies can target:

- The **public transport vehicles** themselves (less energy consuming -motors efficiency, other measures…-, new usage of electricity on board and/or new ways of producing energy on board (e.g. from braking or from vehicle surfaces), new ways of saving energy (e.g. painting, glasses…). It could be:

  > Road-based vehicles, e.g. buses (in such a case the local operational constraints in terms of usage on line and over time have also to be taken into account);

  > Rail-based vehicles, e.g. metro and suburban rail;

  > Or mixed road- and rail-based vehicles, e.g. light rail;

- The **private new clean vehicles** which would be used in complementarity with public transport. In such a case what is at stake for public transport operators and/or authorities is a combination of innovative vehicles and innovative usage, shifting travels from one individual trip using one individual private mode to one shared trip using one individual or shared private mode in a multi-modal combination where new public transport infrastructure at transfer stations offers the proper means to attract new customers.

>> RESEARCH ON SUPPORTING DECISION-MAKERS RE-BALANCING THEIR SUPPORT FOR EVS TOWARDS ELECTRIC MEANS OF PUBLIC TRANSPORT AND BETTER COMBINED USE OF PRIVATE AND PUBLIC VEHICLES <<

- **Energy efficiency and cost savings** need to be considered as closely related features to foster a large acceptance and mass adoption of electro-mobility, easing the emergence of innovators and early adopters. This applies specifically to public transport means. Indeed, EC support is first targeting private cars, while some EU projects have identified a clear need for more financial support for public transport. The **ELIPTIC project**, for instance, claims for the "**factor 100**", aiming at a **better balance of EC support between private and public vehicles, particularly electric buses**;

- The support should also focus on a **better use of private means in combination with public transport**. With regard to urban electro-mobility, the focus should be on shared mobility as it has to solve its own specific barriers and is the best solution to tackle further problems such as congestion. Further testing and market uptake is required in order to increase availability and reliability of:

> electric and alternatively-fuelled buses and their infrastructure;

> individual electric means of transport used in combination with public transport (private cars and other individual means, on-street rental shared electric vehicles like ZenCar in Brussels, rental electric bikes or scooters …);

> Higher capacity transport means, such as BHLS – Bus systems with High Level of Service – Further research about the requirements and specifications for BRT specifically designed for European cities. A set of lessons learnt from the experiences in other countries worldwide could be developed. Infrastructure, rolling stock, operations and socio-economic issues are equally important for the deployment of effective solutions.

>> INNOVATIVE ENERGY INFRASTRUCTURES AND ENERGY STORAGE EQUIPMENT <<

Clean vehicles need **appropriate refuelling infrastructure and/or energy storage equipment** to have them largely adopted by consumers. The location and features of the refuelling facilities - either electric plugs at given parking places or (rack of) charged batteries for an exchange with discharged ones - needs to be carefully chosen.

Studies should consider - also taking account of local background:

• The characteristics of the **infrastructure and equipment required** for refuelling (e.g. hydrogen) or recharging batteries or exchanging battery racks in terms of:

> **Refuelling capabilities and origin of energy:**

– local production (generators); dedicated electricity network for public transport (e.g. in case of metro system); city grid…;

– stored energy either on-board (e.g. flying wheel) or in other places;

> **Space required** (quick charge parking or longer time parking in relation with a trip purpose allowing the vehicle to stay for several hours; storage of batteries on-board or out of the vehicles);

> **Safety and security of components** (e.g. in case of fire or explosion);

> **Environmental impact of the components** (e.g. recycle ability);

• The organisation of **"smart" stations** where this refuelling is organised:

> Transfer stations from individual (private or shared) means to public transport;

> Public transport interchanges (from electric bus to rail modes);

> Depots or garages for (electric) buses and/or tram/light rail; link to the smart (cities) grids;

• The **impact on the overall energy** required, particularly electric power, at a given time to serve all the simultaneous peak refuelling needs on the design of the electricity distribution system, which could be specific to public transport or integrated in the grid serving the whole city (smart cities and smart grids);

• The capabilities of the public transport assets to produce **additional energy** (e.g. bus or tram shelters and generating energy from solar cells on top of them);

- Opportunities of using the roof and windows of the **vehicles** themselves for producing (or saving) part of the energy needed for non-traction needs (HVAC, on-board video, lights, IT platform, ticketing machines, powering passenger artefacts…);

- Different **models of governing the charging stations**: who sets them up and who runs them? How are responsibilities distributed among cities, energy providers and transport providers? What are good models in this regard? These questions need to be solved to enhance the implementation of real EVs infrastructures. Analysis methods and support tools to make informed decisions on the best possible locations of charging infrastructure are also required;

- In terms of human resources, the introduction of new technologies requires the development of the appropriate **skills** for operation and maintenance.

Depending on the degree of innovation and speed of market uptake, the actions to be taken may be in the short-medium term or at a longer term. Decisions about relevant research should take these factors into consideration. The barriers for implementation of new infrastructure pertain likewise to policy-makers and to citizens and other stakeholders. Sustainable transport policies require a lot of investment and changes, and therefore have to be medium to long-term in nature in order to bear fruits.

>> STANDARDS AND POLICIES <<

Any solution addressing a low-carbon transport system must not be limited to a technological discussion on clean vehicles but should also consider the need for regulations and standardisation.

Some EU projects, like many under CIVITAS, conclude that a coordinated approach to electro-mobility needs to include different stakeholders in transport and energy and at different levels (city, region, national, EU…). Such an approach enables cities to reach agreements on their transport and land use policies and to create charging infrastructure which is strategically located at hubs/activity centres and thus linking modes. Indeed, new sustainable mobility schemes in cities should break up past silo approaches and integrate policy and planning approaches that build a global strategy integrating energy, transport and health policy and integrate combined electro-mobility in planning procedures. For instance, as already happened in some countries, strategies on combined mobility could be supported and formalised in the form of integrated planning documents like Sustainable Urban Mobility Plans (SUMPs) in combination with Sustainable Energy Action Plans (SEAPs).

A fragmented clean transport system based on uncoordinated policies could greatly downplay the success of new clean technologies. A range of new policies, measures and actions beyond fuel sources and technological developments have to be studied to allow and encourage a shift from higher emitting modes to lower carbon solutions, taking into consideration an evaluation and prioritisation of the modes/their (combined) usage depending on their use of space and energy. Official political support is required at all levels.

Research could clarify and support:

- The decisions to be taken at the **regulatory level** and by public authorities (city, region, country, EU or even worldwide) for mandatory application in a given territorial area;

- The **micro-economic decisions** to be taken by the relevant market suppliers and end-users through the voluntary development of standards by the appropriate technical stakeholders.

2.3.11. Active and light travel modes

When thinking about mobility, the role of active and light travel modes – namely cycling, walking and motorcycling – is sometimes overlooked and often underestimated. Many of the daily trips in urban areas are conducted by bike or on foot, although the average distance travelled may be less compared to that of motorised transport modes. Moreover, before entering a public transport or private vehicle, one has also already moved on foot or by bike. As such, good public transport is a key enabler for active travel modes and as such unlocks their health benefits. Therefore, cycling and walking must be recognised as being fully part of intermodal travel choices and multimodal travel chains. New technologies (e.g. electrically assisted bicycles) and mobility concepts (e.g. sharing concepts, micro consolidation centres) also emerge and further extend and expand the usability and range of active and light travel modes. In addition, a forward-looking bicycle-friendly infrastructure can foster cargo-cycles that offer alternative sustainable solutions for urban freight transport.

Another light travel mode is the category of powered two-wheelers (PTWs), including powered cycles, mopeds, motorcycles, tricycles and quadricycles (L-category vehicles, as per Regulation EU 168/2013).

Users of light travel modes can be considered as vulnerable road users. The main concerns in addressing VRU relate to the improvement of their safety, mobility and comfort, which would allow these users to be fully integrated into the transport system in a way that adequately responds to their specific needs. Focusing on safety is essential, especially as long as the decrease of the number of fatalities and severe injuries is slower for VRU than for other types of road users. Behavioural aspects remain important, both with regard to VRU themselves, as well as from other traffic participants towards VRU. The degree to which citizens feel safe and are encouraged to use active and light travel modes strongly depends on the design of urban space. The promotion of these modes therefore closely links in with proper urban planning and infrastructure design.

New types of vehicles for VRU have come or are coming to market. All sorts of light electric vehicles (e-bikes, one-wheeled electric vehicles …) for personal transportation attract new users, as they increase speed and/or comfort. An issue to be studied is the interaction with other VRU (pedestrians, cyclists). Regulations are another topic for research: the current trend in urban areas is to reallocate the public space dedicated to different modes of transport. With the quality of life argument in mind, more space is allocated to some categories of VRU (and for public transport). The place for VRU in the renewed design of public space should be optimised.

On the other hand, also VRU suffer from distraction: mobile phone use by VRU in the urban environment has safety impacts. HMI optimization can reduce these risks.

The research challenges with regard to active and light travel modes relate to the following areas:

• Understand people's **needs and expectations**, including those of specific groups such as young and aged citizens, as well as recently immigrated and low-income citizens, for assuring social equity – in order to understand mode choice behaviour – reasons for using active and light modes instead of the car (especially if there is a car in the household) and possibilities to promote their use;

• **Integrate active and light travel modes** in the long-term planning processes of communities, also considering a better integration of safety aspects into SUMPs and horizontal integration of health, transport and environment at the local level;

• Develop **supportive national frameworks** providing for integrated health, environment and transport policies to support sustainable transport modes (vertical integration);

• Determine the possibilities for adapting **urban infrastructure** to promote active and light travel modes;

• Recognise active and light travel modes in transport surveys and transport **modelling**, including transport demand and emissions modelling;

• Study **mobility management** measures that can foster active and light travel modes;

• Analyse the relationship between **built infrastructure**, encouragement and modal choices;

• Investigate **intermodal transport options** in a systematic manner;

• Research the potential of **new technologies**, such as pedelecs, cargo-cycles and alternative propulsion L-category vehicles, for passenger and small logistics transport; analyse the introduction and use of e-bikes for specific target groups such as younger or older people, especially since their risk estimation capabilities are different in an ever faster moving society. Solutions need to be sought to overcome the difficulties they currently experience;

• Study the **interaction between new types of vehicles** for VRU (e-bikes, one-wheeled electric vehicles, etc.) for personal transportation with other VRU (pedestrians, cyclists);

• Identify new **regulations** required to reallocate public space dedicated to different modes of transport, notably sustainable and light modes of transport;

• Study the potential of active and light travel modes in **sharing schemes**;

• Further investigate the connection between transport and health in terms of active travel addressing societal challenges such as obesity and lack of physical activity, including quantifying the health benefits of active travel through the WHO's HEAT tool.

[EXPECTED IMPACTS]

Research may result in updated tools, recommendations and design guidelines for municipalities and planners to cater for the needs of light travel mode users in the best possible way.

Solutions	Research topics	Type of action	Milestone
Clean fuels and vehicles	Standards and policies	Deployment and market introduction	2020
	Mutually supportive technologies and new ways of using them	Deployment and market introduction	2025
	Supporting decision makers to re-balance their support for EVs towards electric means of public transport and better combined use of private and public vehicles	RTD	2025
	Innovative energy infrastructures and energy storage equipment	RTD	2025
	Higher capacity transport means, such as BHLS – Bus systems with High Level of Service	Demo	2025
Active and light travel modes	Needs assessment with regards to active and light travel modes across target groups – understanding modal choice behaviour	RTD	2020
	Integrating (safety aspects) of active and light travel modes in SUMPs	Demo	2025
	Develop supportive national frameworks providing for integral health, environment and transport policies to support sustainable transport modes (vertical integration)	Deployment and market introduction	2025
	Urban infrastructure adaptation, relation between built infrastructure and modal choice	Demo	2025
	Inclusion of active and light travel modes in surveys and modelling	Deployment and market introduction	2025
	New technologies (pedelecs, cargo-cycles, and L-category vehicles – (including safety aspects)	Demo	2025
	The role of active and light travel modes in sharing schemes	RTD	2025
	The connection between transport and health in terms of active travel	RTD	2025

Table 6: Modal solutions - milestones

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