



Research **Urban** Theme **Mobility** Analysis Report

COMMUNICATING TRANSPORT RESEARCH AND INNOVATION

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This report was prepared by:

Gareth Horton, Guy Hitchcock (Ricardo Energy & Environment) Cosimo Chiffi, Angelo Martino (TRT) Claus Doll, Verena Zeidler (Fraunhofer ISI) Hana Bruhova-Foltynova, Zbynek Sperat, Radomira Jordova (CDV) Athena Roumboutsos (University of Aegean) Ian Skinner (TEPR)

Coordinated and guided by: Dimitrios Vartis DG MOVE – Unit C2 (Research & Innovative Transport Systems)

Henriette van Eijl DG MOVE – Unit C2 (Research & Innovative Transport Systems)

> **Design and layout by:** Ricardo Energy & Environment

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# Research Theme Analysis Report Urban Mobility

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## Executive summary

This is the first in the new series of Research Theme Analysis Reports produced under the new Transport Research & Innovation Portal (TRIP) Continuation project for the European Commission's Directorate-General for Mobility and Transport (DG-MOVE). It covers the research theme Urban Mobility.

The purpose of TRIP is to collect, structure, analyse and disseminate the results of EU-supported transport research and research financed nationally in the European Research Area (ERA), together with selected global research programmes. The TRIP web portal can be found at www.transport-research.info

The purpose of this Research Theme Analysis Report is to provide an overview of research performed (mostly) in the EU collated by the TRIP, providing a view across many projects that fall under the theme. It provides an assessment of the reported results from the research projects, giving scientific and policy perspectives.

The theme of Urban Mobility has been divided into seven subthemes, as follows:

- accessibility;
- freight transport;
- intelligent transport systems (ITS);
- low carbon transport technologies;
- sustainable public transport;
- Sustainable Urban Mobility Plans (SUMPs);
- urban land use.

The key findings from a scientific perspective are:

- There is a common trend toward an increasingly integrated approach to urban mobility research. This is particularly evident in the research on SUMPs, freight transport and ITS. This level of integration is likely to increase further and to be applied across all aspects of urban mobility.
- There is a need to continue to develop and deploy vehicle technologies optimised for use in an urban environment, particularly for urban freight transport (e.g. electric microvans, cargo bikes).
- Significant progress continues to be made in the development and demonstration of the use of new vehicle technologies, particularly electric and hydrogen-fuelled zero emission vehicles.
- Multimodal passenger transport solutions to improve public transport have received significant attention and have been demonstrated in a number of projects, in particular under the CIVITAS (City, Vitality, Sustainability) programme.
- There has been a wider involvement of key stakeholders in research projects, such as private freight companies in urban logistics projects and projects in the SUMPs area. However, a greater involvement is still needed, particularly in transposing business models and practices into policy schemes.
- In the area of SUMPs, the funding priorities should focus more on how to create an 'ideal' SUMP, how to analyse the impacts of these plans and of their particular tools and packages of measures, the further use of ITS and intelligent personalised data, new effective tools for





supporting sustainable mobility and analysis of transport behaviour, mode choice awareness raising and stakeholder involvement.

The key findings from a **policy perspective** are:

- The trends in research on accessibility show a clear shift from issues primarily related to the disabled to a broader focus on people with reduced mobility, such as the elderly. This provides an indication of the focus that will be required in future urban developments in Europe to address the challenges of an ageing population.
- The evolving requirements for urban freight transport (e.g. as a result of e-commerce) need to be taken into account in land-use and transport planning, as well as local economic development strategies.
- There is a need to develop an adequate and appropriate infrastructure to support developments in urban freight transport, not only for new concepts for consolidating and delivering goods, but also to support the use of electric freight vehicles operating in urban areas (cargo bicycles and other two-wheeled vehicles, and micro e-vans). The deployment of a charging infrastructure within the whole management and business models for electric freight vehicles are crucial issues to be addressed to boost use among logistic operators and thus achieve a more sustainable urban mobility.
- The ITS domain has addressed and developed a number of specific applications. However, to support an effective and sustainable integration of urban freight transport into urban

network management, additional research effort should be carried out on data collection for planning and policy formulation. Models for data sharing and cost-efficient data collection on urban freight should be considered. This also requires legal expertise related to privacy and competition issues.

- The data privacy aspects, payment allocations and the role of organising bodies with regard to international use of public transport ticketing systems should be clarified. This area of research should cover equity, institutional and market organisation issues rather than pure technical or economic issues.
- Policy intervention may be required for setting standards in the ITS sector to ensure that the technology is able to deliver the expected safety, user satisfaction and competitiveness benefits. In particular, policy is required in relation to autonomous vehicles. This concerns the safety and quality standards for information exchanged between vehicles, infrastructure and control centres. It also includes the question of responsibility in case of a collision involving an autonomous vehicle. Eventually, the question of driving licences with the use of selfdriving cars or the condition of the driver will need to be addressed by policy.
- To date, there is little agreement on the minimum requirements for a SUMP. There is a need to agree on common European standards, to prepare a list of appropriate measures and packages of measures with clear analyses of their various impacts, and to contribute to more precise and easier-to-do evaluations and monitoring of the implementation of SUMPs.

This definition of a SUMP should also include a common European standard for interoperable public transport systems, added value ticketing, payment and added value services – including multimodal transport systems – to replace the numerous national standards that have been developed to date. Binding standards at an EU level would ease the use of public transport and multimodal mobility services for international travellers.

#### The **priority research gaps** identified are:

- There is a need for further research on economic assessments in relation to sustainable public transport. For example, research on urban transport taxation, fare policies, etc.; analysis on financing and social assessment; and evaluation of various public transport services and measures.
- Previous studies have proposed concepts of smart urban logistics with freight distribution centres. However, to date, their impact on real-life freight services in towns and cities is limited.
   Further research is needed on the drivers, barriers and business models for inter-company cooperation on urban territories. A large-scale implementation with a city fully supporting and fostering a smart and co-operative urban freight system would be needed for proving feasibility and impacts.
- A problem not solved by ITS applications for the end users of all transport modes so far is the level and the personalisation of information provided. To impact user behaviour in a certain way, different users need to be addressed in different ways. Respective psychological research (e.g. in combination with response to hazardous events) could be covered by future research programmes.
- To help meet the EU goal of halving the use of conventionally fuelled cars in urban environments by 2030 (and phasing them out in cities by 2050), there should be a research focus on increasing the attractiveness of public transport and how to organise it better, how to build interchange zones/nodes, the development of alternatives for urban motor traffic that are free of carbon dioxide (CO<sub>2</sub>) and building the potential of new or unconventional transport systems and vehicles.
- For hydrogen-fuelled vehicles, there is still a cost and a fuel efficiency problem to be solved. This is particularly relevant to public transport vehicles, which are perhaps most suited for this technology.
- There may be a need to implement incentives to encourage the uptake of low-carbon vehicle technologies and their use in an urban environment. However, despite some good practice examples, it is still not clear how such incentives should be designed to maximise impact and to minimise side effects on other policy goals. Fundamental research of drivers, barriers, risks and opportunities of different incentive structures, including through the EU energy taxation rules, with respect to the great differences in European cities and regions is still lacking.

In general, the analysis of the research being performed in this report indicates that there is relatively little overlap between multiple projects and programmes. Those overlaps that have been identified include:

- There appear to be significant overlaps in research on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication standards and applications.
- Overlaps can be found among research projects on acceptance and awareness within the field of sustainable public transport. The projects analysed bring a large potential for dissemination of best practice, worst practice and lessons learnt to other cities, and the community of researchers and practitioners.
- Synergies can be found among the projects on SUMPs. In particular, there are strong synergies between the CIVITAS projects and research projects on specific issues such as transport behaviour analyses. The CIVITAS projects benefit from the findings of other research projects. Equally, the research community builds on the experience and findings of case studies of measures applied in the CIVITAS demonstration cities. The CIVITAS projects and other related research are now being brought together under a single umbrella, CIVITAS 2020 (part of Horizon 2020), which is likely to reduce any overlaps.

The research agenda on urban mobility is driven by a number of key challenges and trends that are being faced in cities across Europe and which are the focus of European policy objectives. These cover:

- Increasing urbanisation. Over 70 % of the European population lives in urban areas and this percentage is increasing with time. This puts pressure on urban transport systems, leading to increased congestion, collisions and environmental impacts, all of which impair urban mobility.
- Ageing populations. As human life expectancy increases, there is a need to cater for an ageing population that may have physical disabilities and different transport needs. This brings new requirements for accessibility and sustainable public transport.
- **Developments in communications**. Information technology is changing the way people communicate and access goods and services, and so affects the requirements for travel. E-commerce is impacting on the requirement for urban goods delivery, teleworking is reducing the need to travel and both are influencing how we use urban space.
- **Road congestion**. This is a key issue threatening urban mobility. Innovative technologies and measures are required to manage road use in urban areas.
- Collisions and safety. Collision rates have been dropping in Europe, but safety is still a key driver of transport policy and research.

 Greenhouse gas and air-quality-related emissions. These are perhaps the key environmental impacts of urban mobility. Low or zero emissions vehicles may be part of the solution, but other measures (such as the promotion of walking and cycling, and greater use of sustainable public transport) are also required.

The projects reviewed across the Urban Mobility Research theme are tackling all of the key policy objectives of the European Commission with no clear gaps. However, the research is still not really progressing the 'step-change' in urban mobility that Europe needs to tackle the issues of congestion and pollution. For example, there is much innovative research on telematics and new vehicle technologies, but they are primarily being used to do what we do now better, rather than do things differently. Also, electric and fuel cell technology is being used now in existing types of road vehicles but, as new technologies, they could have the potential to bring greater changes to wider mobility patterns.

Research in communication and telematics for intelligent roads has resulted in the development of numerous algorithms and data standards for V2V and V2I communication. However, to date, none of these standards has become universal due to the business protection interests of the industries participating in the research or the different requirements and applications of the systems. Thus, there are significant barriers to the transferability of the solutions that have been developed to date.

This review suggests that a lot of good technical research has been carried out and that there is plenty of good practice at the practical level. Key barriers to greater application of the research include:

- Institutional issues at the city level coordination and cooperation between city departments and more innovative approaches to public-private partnership (PPP) (especially in relation to urban freight).
- **Standardisation issues** this is a particular barrier for ITS and cargo units in urban freight. In both cases, this is partly driven by protecting private business interests as technologies are developed, but also in relation to new vehicle technologies and refuelling infrastructure.
- Sharing knowledge and greater involvement of stakeholders – there is a huge amount of knowledge and information generated from research projects related to urban mobility. However, although efforts are always made to disseminate the results, including via fora such as CIVITAS, the expertise that has been generated tends to remain in the hands of the leading cities and practitioners.

Therefore, there is a need for an increased focus on the issues associated with practical implementation of research outcomes alongside the innovations and new technology. The outcomes also need to be disseminated to all groups with an interest in urban mobility, with key stakeholders being involved from the outset.

Recommendations made from this review, with the aim of further improving the outputs from the research on urban mobility, include:

- Continue to develop and promote an integrated approach to urban mobility research. Priority should be given to projects that aim to work across different transport modes and address combinations of challenges.
- Develop and trial new mobility concepts. Apply and integrate technologies innovatively with the aim of achieving a 'step change' in urban mobility patterns.
- Ensure that institutional and implementation issues are tackled as part of the research, so that the outcomes bring solutions closer to use in practice.
- Engage key stakeholders from the outset. Work with key implementers and innovators to help the uptake of the ideas beyond the project.
- Continue with the core technology research in ITS, vehicles and fuels. These technologies are expected to provide the building blocks for an innovative, integrated and comprehensive approach to urban mobility. However, it is also important to seek new solutions appropriate for the urban context such as urban-specific delivery vehicles.



## 1 Introduction

This is the first in a new series of research theme analysis reports produced under the new Transport Research & Innovation Portal (TRIP) continuation project for the European Commission's Directorate-General for Mobility and Transport (DG-MOVE). It covers the Urban Mobility research theme.

The purpose of TRIP is to collect, structure, analyse and disseminate the results of EU-supported transport research, research financed nationally in the European Research Area (ERA) and selected global research programmes. The TRIP web portal can be found at www.transport-research.info

This research theme analysis report gives an overview of research performed (mostly) in the EU collated by TRIP, providing a view across many projects that fall under the theme title. It provides an assessment of the reported results from these projects and offers perspectives from scientific and policy points of view.

This assessment aims to consider:

- overall trends in the research, including key results;
- · overall trends in the research funding;
- the alignment of the research with current policy;
- · policy implications of the results from the research;
- any gaps in the research theme.

The theme for this analysis was decided in consultation with DG-MOVE. To ensure that all relevant projects were included in the analysis, the project search in the TRIP database was extended beyond the most obvious relevant category (urban transport) to include:

- accessibility, social and equity impacts;
- environmental impacts;
- freight transport;
- intelligent transport systems (ITS);
- land-use and transport planning;
- multimodal transport;
- passenger transport;
- transport management.

Further projects were identified from other research themes by searching for 'mobility'.

The assessments for this analysis have been performed on a number of sub-themes within the Urban Mobility theme. The projects identified have been clustered under these sub-themes. The analyses of the trends and gaps have been performed across the projects in the sub-themes and across the full Urban Mobility theme. The set of sub-themes, selected following initial assessments of the projects and in consultation with DG-MOVE, comprises:

- accessibility;
- freight transport;
- ITS;
- low carbon transport technologies;
- sustainable public transport;
- Sustainable Urban Mobility Plans;
- urban land use.

By the nature of the analysis being performed, the assessments of trends and gaps are based on the projects selected from those within the TRIP and are not able to take account of the results of research that was not identified through this process. It is worth noting that European Commission-funded projects are naturally aligned with EU policy through the funding and selection process. As such, the trends identified from these projects may not necessarily be representative of those from further afield.

Section 2 of this report presents a high-level review of the Urban Mobility theme, and includes policy and research highlights. The subsequent sections then present reviews of the individual sub-themes (as specified above) including preliminary recommendations, the research environment and development, and the research activities and outcomes. Conclusions and recommendations are presented at the end of the report.



## 2 Policy and research highlights

#### 2.1 Scope of the Urban Mobility theme

Urban mobility is a wide-ranging topic that can be broadly described as covering the movement of people and goods in an urban area, and the aspects of the transport system and urban environment that affect this. Under this overall theme, the following seven specific sub-themes have been identified to help categorise the research:

- accessibility focusing primarily on the physical access to the transport system;
- freight transport looking at urban logistics;
- intelligent transport systems (ITS) considering the role that these play in managing urban transport systems and activity;
- low carbon transport technologies technology aspects of the transport system that help reduce carbon emissions;
- sustainable public transport wider sustainability of the public transport system;
- Sustainable Urban Mobility Plans (SUMPs) the development of an integrated approach to transport, economic and landuse planning;
- urban land use the impact of the wider urban form on mobility.

These themes are not independent of each other and there are significant linkages and overlaps between them, as shown in Figure 2-1. For example, low carbon goods vehicles and ITS technologies for urban logistics link the themes on freight transport, ITS and low carbon technologies. Similarly, SUMPs link to sustainable public transport, urban land use and accessibility.

The research activity under these sub-themes has been drawn primarily from the urban transport category in the TRIP (www.transport-research.info) database. However, projects have also been drawn from other areas of the TRIP database where they match the Urban Mobility theme, such as:

- · accessibility, social and equity impacts;
- · environmental impacts;
- freight transport;
- ITS;
- land-use and transport planning;
- multimodal transport;
- passenger transport;
- transport management.

#### 2.2 Policy context

European transport policy focuses on the efficiency, competitiveness and environmental performance of the transport system at the European level. Therefore, it has a greater emphasis on inter urban and transnational transport (such as the work on



the Trans-European Network – Transport (TEN-T) core network) than on urban mobility per se. However, as over 70 % of people in Europe live in urban areas, a significant amount of transport activity occurs in or is generated by these areas. Therefore, urban transport and, more widely, urban mobility is crucial to the functioning of the European transport system.

Although the responsibility for urban mobility policies lies primarily with local and national authorities, there is a role for European policy to provide a framework for consistent and coordinated action across cities in Europe. The role of European policy and activity was set out in the European Commission's 'Action Plan on Urban Mobility' in 2009 (European Commission, 2009). The key themes in this were:

- promoting integrated policies in particular, the role of SUMPs;
- focusing on citizens in terms of accessible transport systems and passenger information and services;
- greening urban transport with a focus on low carbon vehicles and low emission driving styles;
- strengthening funding looking primarily at pricing mechanisms;
- sharing experience and knowledge through data and statistics, and research and demonstration projects;
- optimising urban mobility looking at urban freight and ITS.

Figure 2-1 Linkages between the Urban Mobility sub-

Key aspects of the Action Plan on Urban Mobility were taken through to the Commission's Transport White Paper 'Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system' (European Commission, 2011). The core aim of this policy document was to move Europe to a more efficient and competitive transport system, while achieving a 60 % reduction in greenhouse gas (GHG) emissions by 2050. In total, 10 key goals are set out in the White Paper for the European transport system and the following are those that relate to urban mobility:

- Halve the use of 'conventionally fuelled' cars in urban transport by 2030, phase them out in cities by 2050 and achieve logistics that are essentially free of carbon dioxide (CO<sub>2</sub>) in major urban centres 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.
- By 2020, establish the framework for a European multimodal transport information, management and payment system that is relevant for urban ITS.
- By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims to halve road casualties by 2020 – with a key component being urban road safety.
- Move towards full application of 'user pays' and 'polluter pays' principles relating to urban road pricing and public transport pricing.

Building on the Transport White Paper and recognising the importance of urban mobility within the wider European transport system, the Commission developed an urban mobility package in 2013 (European Commission, 2013) stating 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 ... the Commission will strengthen its actions on sustainable urban mobility in areas where there is EU added value.'

This mobility package identified five key areas for action:

- greater implementation of SUMPs;
- more action on urban logistics;
- a consistent and more proactive approach to access regulations and road-user charging;
- development of urban ITS;
- · further action on urban road safety.

The relationship between these core policy documents and the Urban Mobility research sub-themes is shown in Table 2-1.

Overall, the sub-themes identified and reviewed under urban mobility provide a direct coverage of most of the core policy objectives at the European level. Other policy objectives span a number of areas – in particular, urban safety and transport pricing are aspects of several research themes.

Urban Mobility theme	Action Plan on Urban Mobility	Transport White Paper	Urban mobility package
Accessibility	Focusing on citizens	Accessibility of TEN-T	
Freight transport	Optimising urban mobility	CO <sub>2</sub> free city logistics; TEN-T nodes	More action on urban logistics
ITS	Optimising urban mobility	Multimodal transport information, management and payment system	Development of ITS
Low carbon technologies	Greening urban transport	Halve the use of 'conventionally fuelled' cars in urban transport and CO <sub>2</sub> -free city logistics	
Sustainable public transport	Focusing on citizens; greening urban transport	TEN-T nodes	
SUMPs	Promoting integrated policies		Implementation of SUMPs
Urban land use	Promoting integrated policies	TEN-T nodes	Implementation of SUMPs

#### Table 2-1 Relationship between the Urban Mobility sub-themes and key European policy documents

#### 2.3 Research environment and development

The research agenda is driven by a number of key societal challenges and trends that are being faced with regards to urban mobility across cities in Europe and are the focus of the European policy objectives. These challenges have been identified in key Commission policy documents such as the Transport White Paper, Action Plan on Urban Mobility and in the individual research themes. They primarily cover:

- Increasing urbanisation more than 70% of the European population lives in urban areas and this is increasing. This is putting pressure on urban transport systems leading to congestion, collisions and environmental impacts, all of which are impairing urban mobility.
- Ageing populations the population of Europe is ageing as people live longer. Therefore, to maintain and improve urban mobility transport systems, there is a need to cater for this ageing population who may have physical disabilities and different transport needs (e.g. less commuting for work). This has been a key driver for accessibility research, but is also important for sustainable public transport, SUMPs and urban land use.
- Developments in communications IT systems are changing the way we communicate and access goods and services, so affecting the way we travel. E-commerce is having an impact on the need for urban goods delivery and teleworking is reducing the need to travel – both are influencing how we use urban space. This is a consideration in urban logistics, urban land use, travel information and SUMPs.
- Congestion this is one of the key issues threatening urban mobility. It is a driver for urban ITS seeking to maximise use of the existing infrastructure, sustainable public transport aiming to generate modal shift away from car-based travel, and SUMPs and urban land use aimed at managing transport demand.
- Collisions and safety collision rates have been dropping in Europe, but safety is still a key driver of transport policy and research. ITS systems, designed to share information between vehicles and with the infrastructure, are targeting a reduction in collision rates. SUMPs will be used to improve safety for all transport modes.
- GHG and air-quality-related emissions these emissions are perhaps the key environmental impacts of urban mobility. They are the key drivers for low carbon and low emission transport technologies. However, such technologies are only part of the solution. Work on SUMPs to promote walking cycling and the use of sustainable public transport to generate modal shift is also aimed at tackling this issue.

A common theme is an increasingly integrated approach to urban mobility research. This is picked up most strongly in the SUMP work, which is driving an integrated approach to urban transport and land-use planning, and covers all aspects of mobility and engages a wide range of stakeholders. Similarly, urban freight research is now seen as part of the wider urban mobility agenda and how that agenda is driving changes in the use of urban space and passenger transport. Also, many ITS projects focus on improving urban logistics or public transport through improved information and data exchange. In addition, projects are tackling a range of challenges that affect urban mobility.

Projects reviewed across the Urban Mobility theme cover all of the key policy objectives of the European Commission with no clear gaps. The political priorities may change over time (for example, road-user charging was an active area of research in the late 1990s and early 2000s, but has had less attention lately due to the reduction in political will to approach this sensitive subject with city residents).

One observation that could be made is that the research is still not really progressing the 'step-change' in urban mobility that Europe needs to tackle the issues of congestion and pollution. There is much innovative research on telematics and new vehicle technologies, but they are primarily being used to do what we do now better, rather than doing things differently. For example, telematics is largely being used to make better use of existing infrastructure or to make existing car travel safer. There seems a reluctance to move beyond the current mobility system to new concepts of mobility services and products in any significant way. This is most likely because of institutional inertia and vested interests in the existing system. So, the questions being raised in the research reviews are issues such as:

- Electric and fuel cell technology is being used in existing vehicles but, as new technologies, can they change our wider mobility patterns?
- ITS are moving from centralised systems to autonomous systems, but rather than just autonomous cars can this generate new mobility services?
- New vehicle technologies and ITS are not really being considered in urban land use to make a step change in the way we use our cities.
- Is there further integration between modes that can be achieved, such as links between urban logistics and public transport or between long-distance transport (trains and buses) and local delivery systems (electric micro-vans and cargo bikes)?

#### 2.4 Research activities and outcomes

The research reviewed from TRIP has identified key research achievements across the Urban Mobility theme covering:

 Much greater integration between modes and activities – such as integrating urban freight considerations into urban transport planning and management, which has traditionally focused on passenger transport. 'ENergy efficiency in City LOgistics Services for small and mid-sized European Historic Towns' (ENCLOSE, 2012-2013) and 'Clean Last mile transport and logistics management for smart and Efficient local Governments in Europe' (C-LIEGE, 2011-2013) are good examples of this integration as they provide guidelines for the development of city logistics plans.

- Development and use of new vehicle technologies particularly for electric and hydrogen fuel cell vehicles as low carbon or zero emission vehicles. The 'Clean Urban Transport for Europe' (CUTE, 2006) project was a good example of this.
- The move from central to autonomous ITS changes in communications technology and computing power have enabled this move and it has been demonstrated in projects such as 'Cybernetic technologies for the car in the city' (CyberCars-2, 2008).
- Multimodal passenger transport solutions to improve public transport – these were demonstrated in a number of projects, in particular under the different editions of the CIVITAS (City, Vitality, Sustainability) programme (e.g. the 'Mobility Initiatives for Local Integration and Sustainability' (MOBILIS, 2009) and 'Transport & Environment Alliance for Urban Sustainability' (TELLUS, 2006) projects).
- Wider involvement of key stakeholders in research projects – such as key private freight companies in urban logistics projects and projects in the SUMP area.

In general, the review suggests that a lot of good technical research has been carried out and that there is plenty of good practice at the practical level. However, the key barriers to greater application of the research would seem to be:

- Institutional issues at the city level coordination and cooperation between city departments and more innovative approaches to public-private partnership (PPP) (especially in relation to urban freight).
- Standardisation issues this is a particular barrier for ITS. Some of this is driven by protecting private business interests as technologies are developed and in relation to new vehicle technologies, cargo units for urban freight and refuelling infrastructure.
- Sharing knowledge and greater involvement of stakeholders – there is a huge amount of knowledge and information generated from these research projects. However, although efforts are always made to disseminate the results and specific projects focus on this (e.g. the CIVITAS programme and support projects such as the 'EU-wide establishment of enduring national and European support networks for sustainable urban mobility' (ENDURANCE, 2013), the expertise tends to remain in the hands of the leading cities and practitioners.

Therefore, going forward, it would seem necessary to have an increased focus on the issues associated with the practical implementation of research outcomes alongside the innovations and new technologies. These outcomes also need to be disseminated to all groups with an interest in urban mobility, with key stakeholders being involved from the outset.

#### 2.5 Preliminary recommendations

Overall, significant research outputs are being generated on urban mobility. These are largely addressing the main policy objectives in this area, if not to the degree that will achieve the 'step-change' in urban mobility that is needed. In terms of taking this research area forward with the aim of further improving the outputs, the following recommendations are made:

- it is important to continue to develop and promote an integrated approach to urban mobility research – priority should be given to projects looking to work across different transport modes and addressing a combination of challenges;
- **develop and trial new mobility concepts** applying and integrating technologies and innovation in new ways with the aim of achieving a 'step-change' in urban mobility patterns;
- ensure that institutional and implementation issues are tackled as part of the research – so that solutions are brought closer to practical use at the completion of the work;
- engage key stakeholders from the outset work with key implementers as well as innovators to help the uptake of the ideas beyond the research project;
- continue with the core technology research in ITS, vehicles and fuels – providing the building blocks for an innovative, integrated and comprehensive approach to urban mobility, but seeking new solutions appropriate for the urban context (such as urban-specific delivery vehicles).



## 3 Sub-theme assessments

#### 3.1 Accessibility

#### 3.1.1 Preliminary recommendations

Common outcomes from all the research projects included under the accessibility sub-theme, with particular reference to the Commission's Transport White Paper 'Roadmap to a single European Transport Area – Towards a competitive and resource efficient transport system' (2011), are:

- · 'infrastructure shapes mobility';
- there is a need to attain a 'higher share of collective transport' through improvements in accessibility.

In this context, older research findings are still valuable and contribute to current policy targets. They also contribute to all eight priorities of the European Commission's 'European Disability Strategy 2010-2020' (EC, 2010).

However, it is recognised that the needs of accessibility in the future will be different to those of the past due to the different profile and mobility patterns of the elderly and those with reduced mobility. This is a challenge and a positive prospect as intelligent systems, web-based applications and more sustainable transport options may be endorsed. The EU's Seventh Framework Programme for Research and Technological Development (FP7) project 'Mobility Schemes Ensuring Accessibility of Public Transport for all Users' (ACCESS2ALL, 2008-2010) provided such a research roadmap.

#### 3.1.2 Research environment and development

The Transport White Paper contains targets relating to the accessibility to transport services (see text box). While these targets pertain to all, they are of paramount importance to people with reduced mobility, especially as the percentage

of the elderly in the population grows. In this context, the core of the accessibility sub-theme remains high on the transport policy agenda, with the research being shaped by new technological developments under other sub-themes (e.g. Intelligent Transport Systems (ITS)) in combination with the behavioural profile of the user population.

'The quality, accessibility and reliability of transport services will gain increasing importance in the coming years, inter alia due to the ageing of the population and the need to promote public transport. Attractive frequencies, comfort, easy access, reliability of services, and intermodal integration are the main characteristics of service quality. The availability of information over travelling time and routing alternatives is equally relevant to ensure seamless door-todoor mobility'

Extract from the European Commission's 2011 Transport White Paper



#### 3.1.3 Research activities and outcomes

Under this sub-theme, seven research projects were analysed – four were financed by various European programmes and three by national programmes. Table 3-1 summarises projects included in this analysis, their duration and source of funding.

These projects were implemented between 2004 and 2013, and their topics indicate a progressive shift from a focus on the disabled to a broader consideration of people with reduced mobility (including disabled and the elderly). Those with reduced mobility are defined as:

'People who have difficulty when using public transport, such as disabled people (including people with sensory and intellectual impairments, and wheelchair users), people with limb impairments, people of small stature, people with heavy luggage, elderly people, pregnant women, people with shopping trolleys, and people with children (including children seated in pushchairs)'<sup>1</sup>.

More specifically, the earlier projects focusing on the disabled concern:

- The provision of signalling, information and guidance for the blind and partially sighted people by exploiting advancements in technology ('Interactive audible information system for the mobility of blind persons in public transport', RAMPE).
- The protection of provisions (parking spaces) specifically designed for the use of disabled people (Tackling the Abuse of Off-street Parking for Disabled People in Scotland, 2005). The project recognised the need to raise awareness in

Table 3-1 F	Projects	identified	for the	accessibility	sub-theme
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respecting the needs of the disabled and the introduction of the requirement to include the needs of people with reduced mobility when implementing these special provisions.

The scope of the later projects was widened to include the elderly and people with reduced mobility. They concern:

- The development of systems to support the physical accessibility to public transport. The FP7 project Public Transportation – Accessibility for All (Pubtrans4all, 2012) set out to develop a prototype vehicle-based boarding assistance system that can be built into new rail vehicles or retrofitted into existing rail vehicles to improve accessibility.
- The cost of travel potentially limiting mobility. Urban public policies with reduced fare policies try to address this issue.
   However, there is a cost to the public budget for this and it requires careful monitoring (Scotland-wide Older and Disabled Persons Concessionary Bus Scheme, Further Reimbursement Research, 2013).
- The design of urban space for an aging society (Urbaging, 2009) in an approach that supports and allows the mobility and inclusion in the community of all citizens. It also recognises that the elderly of 2040 will be more active.
- The preparation of the urban mobility plans based on the physical and mental characteristics of future older people (Growing Older, stAying mobile, GOAL, 2013). These characteristics are used to explore, in a structured way, their needs while driving, using public transport, walking and cycling, and the relevant information needed before and during travel.

Project acronym	Project name	Project duration	Source of funding
RAMPE	Interactive audible information system for the mobility of blind persons in public transport	01/2004-01/2006	PREDIT 3: Operational Group 2 – Mobility services
N/A	Tackling the Abuse of Off-street Parking for Disabled People in Scotland	11/2005-07/2007	Scottish Government
Urbaging	Designing urban space for an ageing society	06/2007-06/2009	Switzerland National Research Programme (NRP) 54 – Sustainable Development of the Built Environment
ACCESS2ALL	Mobility Schemes Ensuring Accessibility of Public Transport for all Users	12/2008-11/2010	European (FP7)
MEDIATE	Methodology for Describing the Accessibility of Transport in Europe	12/2008-11/2010	European (FP7)
PUBTRANS4ALL	Public transportation – Accessibility for all	09/2009-11/2012	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the Transport programme (TPT)
GOAL	Growing Older, staying mobile: The transport needs of an ageing society	09/2011-09/2013	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the Transport programme (TPT)
N/A	Scotland-wide Older and Disabled Persons Concessionary Bus Scheme – Further Reimbursement Research	05/2012-02/2013	Transport Scotland

<sup>1</sup> The definition is taken from Directive 2001/85/EC relating to special provisions for vehicles used for the carriage of passengers comprising more than eight seats in addition to the driver's seat, and amending Directives 70/156/EEC and 97/27/EC – http://europa.eu.int/eurlex/pri/en/oj/dat/2002/l\_042/ l\_04220020213en00010102.pdf

The above is based on the few projects related to the accessibility sub-theme in the TRIP database. However, it is also worth revisiting older research findings that focus on disabled users to identify their applicability to the elderly and people with reduced mobility in general. The sub-theme is also linked to the ITS and urban land use sub-themes.

The FP7 programme funded two landmark initiatives which aimed to support standardisation and set the research agenda. More specifically, the project Methodology for Describing the Accessibility of Transport in Europe (MEDIATE, 2008-2010) provided a set of common European indicators for describing accessibility, a self-assessment tool for measuring accessibility of urban transport, good practices and the creation of an end-user platform representing a broad range of passenger groups. The ACCESS2ALL project (2008-2010) proposed a research roadmap towards an accessible public transport system for all, based on initiatives already under way, existing legislation and advancements in other domains. The combination of these two projects provides guidance for future development and research.

#### 3.2 Urban freight transport

#### 3.2.1 Preliminary recommendations

In comparison to passenger transport, urban freight transport has received little attention in urban transport policy-making over a long period of time. Various elements may have led to such an 'absence of strategy'. These include the fact that urban freight transport demand and supply are largely determined by private sector organisations, and that freight flows are often driven by processes that are independent of the local context (e.g. global supply chains). Nevertheless, there is no doubt that untargeted public policies and an absence of coordination of urban logistics stakeholders can undermine the potential to achieve positive results in overall urban mobility in the long term.

This lack of proper consideration has also characterised the research effort to a large extent, especially with regard to transport surveys and models. Data and sources of information regarding urban goods movement were quite abundant in the 1960s and 1970s, especially in the US, Australia, and some European and Latin American cities. After this, urban freight, as a focus for data collection and modelling, disappeared until the early 1990s (Dablanc, 2009, World Bank, 2009).

Over recent years, several improvements have been made in terms of understanding city logistics functioning, logic and complexity, characteristics of the different supply chains, technology advancements (e.g. in vehicles, cargo units and ITS) and dedicated infrastructure (e.g. urban consolidation centres and loading bays). This understanding has also been important for impact assessments. In Europe, this improvement is due more to EU research projects than to national programmes, with the exception of the French 'Programme for Land Transport Research and Innovation' (PREDIT) that focused on urban freight transport during its 2nd edition from 1996 to 2000. The increasingly key role that is being assigned to city logistics is still not fully integrated into land-use and transport planning, and local economic development strategies. The initial gap with passenger-centred transport policy and research is less marked nowadays, but many challenges are still to be faced (e.g. in modularity and standards for vehicles and cargo units, and in collaborative logistics).

Research in urban freight transport should continue to explore the potential of, and the impacts on, supply chains of established trends, such as e-commerce and home deliveries, or emerging trends, such as the internet of things (IoT).

Research programmes and EU policies have been making important steps towards integrating urban freight transport into the urban mobility strategy and political agenda.

The analysis of the urban freight transport sub-theme has been split further into different topics. Preliminary recommendations for these topics are given below.

#### 3.2.1.1 Vehicles and fuels

Building on the results of previous projects, research should continue to address the following topics:

- analysing the potential improvements that alternative fuels (including electricity) would offer in the urban environment;
- defining future optimal urban freight vehicle sizes and architectures from a multi-stakeholder perspective;
- developing innovative alternative vehicles including cargo bikes;
- lowering the noise related to handling, loading and unloading of goods to enable night deliveries;
- developing new materials for vehicles and improve the characteristics of the vehicles (less weight and resistance, etc.).

In addition, the 'Urban Freight research roadmap' (2015) produced by the European Road Transport Research Advisory Council (ERTRAC) and Alliance for Logistics Innovation through Collaboration in Europe (ALICE) (ERTRAC-ALICE) indicates the following new research topics:

- facilitate access to delivery areas;
- semi-automation/automation of vehicles (vehicle manoeuvrability and driver assistance);
- driver support and visibility equipment for 360° safety around the vehicle when driving and manoeuvring, including messages to vulnerable users, communication via lights, and audible warning sounds when backing up and operating tail lifts.

The topic of automation of vehicles is also linked to some recent research including exploration and testing activities on the use of unmanned aerial vehicles (UAVs) or microdrones in logistics.



#### 3.2.1.2 Load units and intermodalities

Despite some recent achievements on this topic, the number of projects focusing on load units and intermodal solutions for urban freight transport is quite low. Therefore, the following aspects should be addressed further by research in relation to load unit improvement and efficiency:

- standardised and modular logistics units for a better load factor and interoperability among different transport systems and modes;
- loading rate measurement systems (weight, volume, etc.), to be linked with overall city access control and network management;
- technologies to transfer loads between vehicles (large and small) and other transport modes (holistic multimodal approach).

#### 3.2.1.3 Infrastructure

Research projects in this area suggest that future studies should continue to support the exploration of new concepts for flexible pick-up point networks that could positively impact on costs and delivery times. These include offices, public transport hubs, parking, neighbourhoods for retired people, and private and public vehicles. Under this perspective, the potential operation of urban consolidation centres (UCCs) – and especially urban micro-consolidation centres – is another topic that needs further consideration.

The need for adequate infrastructure to support urban freight transport is not only related to the development of new concepts for consolidating and delivering goods, but also to support the use of electric freight vehicles operating in urban areas (cargo bicycles and other two-wheeled vehicles, and micro e-vans). The deployment of a charging infrastructure within the whole management and business models for electric freight vehicles are crucial issues to be addressed to boost use among logistic operators and thus achieve a more sustainable urban mobility.

#### 3.2.1.4 ITS

To support an effective integration of freight transport into urban network management, additional research effort in the ITS domain should be carried out – particularly on data collection for planning and policy formulation. Models for data sharing and cost-efficient data collection on urban freight should be considered. This also requires legal expertise related to privacy and competition issues.

There is a need for further work on improving current freight models and the better integration of urban freight in main traffic models. The goal should be to move towards realtime information exchange based on highly accurate and dynamically updated maps and positioning systems. In this respect, research should investigate the potential of e-Freight, the internet of things (IoT), the future internet for logistics and, in particular, measures to improve and maximise the availability and (cross-border/cross-system) interoperability of transport data and information systems.

#### 3.2.1.5 Policies and stakeholder involvement

Research should continue to focus on better ways to involve public stakeholders, private stakeholders and actors in the urban freight decision-making process.

Stakeholder cooperation and public acceptance is crucial in long-term sustainable urban mobility planning and in shortterm regulatory issues, such as access restrictions and time windows for city delivery. As well as improving involvement strategies to foster city policies, research efforts should also try to investigate further the potential of collaborative logistics.

#### 3.2.2 Research environment and development

A total of 20 research projects were analysed under the urban freight transport sub-theme. All of them were financed by various European programmes and are listed in Table 3-2 with their duration and source of funding.

Project acronym	Project name	Project duration	Source of funding
IDIOMA	Innovative distribution with intermodal freight operation in metropolitan areas	12/1998-05/2001	EU Fourth Framework Programme for Research and Technological Development (FP4) – Transport Research and Technological Development
MOSCA	Decision Support System For Integrated Door-To-Door Delivery: Planning and Control in Logistic Chains	07/2001-07/2003	EU Fifth Framework Programme for Research and Technological Development (FP5) – IST – KA1 – Systems and services for the citizens
CITY FREIGHT	Inter- and Intra- Urban Freight Distribution Networks	01/2002-02/2004	FP5 EESD KA4 – City of Tomorrow and Cultural Heritage
D2D	Demonstration of an integrated management and communication system for door-to-door intermodal freight transport operations	03/2002-03/2005	FP5 – GROWTH – KA2 – Sustainable Mobility and Intermodality
CREATING	Concepts to Reduce Environmental Impact and Attain Optimal Transport Performance by Inland Navigation	06/2004-05/2008	EU Sixth Framework Programme for Research and Technological Development (FP6) -SUSTDEV-2 – Sustainable Surface Transport
GREEN	Green Heavy Duty Engine	03/2005-05/2008	FP6-SUSTDEV-3 – Global Change and Ecosystems
CATRIN	Cost Allocation of Transport Infrastructure Cost	09/2005-03/2009	FP6-SUSTDEV-2 – Sustainable Surface Transport
PROMIT	Promote Innovative Intermodal Freight Transport	03/2006-03/2009	FP6-SUSTDEV – Sustainable Development, Global Change and Ecosystems – Priority Thematic Area 6 (PTA6)
HEAVYROUTE	Intelligent Route Guidance of Heavy Vehicles	09/2006-02/2009	FP6-SUSTDEV-2 – Sustainable Surface Transport
CHINOS	Container Handling in Intermodal Nodes – Optimal and Secure	10/2006-05/2010	FP6-SUSTDEV-2 – Sustainable Surface Transport
SMARTFREIGHT	Smart Freight Transport in Urban Areas	01/2008-06/2010	FP7-ICT – Information and Communication Technologies
INTEGRITY	Intermodal Global Door-to-door Container Supply Chain Visibility	06/2008-10/2011	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
FREIGHTVISION	Freight Transport FORESIGHT 2050	09/2008-03/2010	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
TURBLOG-WW	Transferability of Urban Logistics Concepts and Practices from a World Wide Perspective	10/2009-09/2011	FP7-SST – Sustainable Surface Transport
CITYLOG	Sustainability and Efficiency of City Logistics	01/2010-12/2012	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
CITY MOVE	City multi-Role Optimised Vehicle	01/2010-12/2013	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
LOGISTICS FOR LIFE	Logistics Industry Coalition for Long- term, ICT-based Freight Transport Efficiency	01/2010-06/2012	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
TRAILBLAZER	Transport and Innovation Logistics by Local Authorities with a Zest for Efficiency and Realization	07/2010-06/2013	Intelligent Energy Europe (IEE)
COFRET	Carbon footprint of freight transport	06/2011-11/2013	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
MOVE IT!	Modernisation of Vessels for Inland	11/2011-10/2014	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the

transport programme (TPT)

#### Table 3-2 Projects identified for urban freight transport sub-theme

The urban freight transport research environment has undergone significant changes over recent years. More projects are now targeted at fully integrating freight distribution in the overall urban mobility strategy, with emphasis on the practical implementation of innovative urban distribution concepts and with the involvement of major players from the express delivery industry.

The evolution of urban freight transport clearly benefits from research activities in the mobility sector, such as:

- · introducing cleaner/more efficient engines;
- using lighter materials and innovative components for trucks and vans;
- developing cooperative intelligent transport systems (C-ITS) and data-sharing experiences;
- using radio frequency identification (RFID) applications for picking goods (as in the 'Container Handling in Intermodal Nodes – Optimal and Secure' project (CHINOS, 2006-2010)).

It is important to note that, more than simply taking advantage of research advancements in generalised freight and logistics or vehicle technology, urban freight transport research projects have themselves produced impacts on the overall research environment.

An example is the PIEK project (PIEK, n.d.)<sup>2</sup>. This was developed by the Dutch Administration following the introduction in 1998 of standards for noise emission during loading and unloading in retail trade and craft businesses. In 2004, the PIEK certification scheme was introduced for vehicles and equipment operating under 60 dB (A), suitable for night-time deliveries without causing noise disturbance. Vehicle adaptations were also tested during the CIVITAS 'Multi-Initiative for Rationalised Accessibility and Clean Liveable Environments' (MIRACLES) project in Barcelona (Eltis, 2003). The broader Sixth Framework Programme (FP6) project 'Quieter Surface Transport' (SILENCE, 2005-2008) further developed an integrated system of methodologies and technologies for an efficient reduction of urban traffic noise.

The policy environment has also changed over recent years. The inclusion of specific policy targets for city logistics at the EU level provided a clear policy framework under which research priorities can be more effectively addressed.

 The 'Conference on Urban Freight Transport and Logistics' organised by the European Commission and the Belgian presidency in 2010 (EC Europa, 2010) brought together highlevel representatives from the European institutions and from key stakeholder associations to debate on sustainable solutions to urban freight in Europe's cities. The conference produced a list of requested EU actions that were more or less transposed into policy intervention (e.g. use of inland ports for urban distribution, best practice and guidance in urban freight planning, data-sharing and cooperative schemes).

- The European Commission's 2011 Transport White Paper 'Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system' (European Commission, 2011) set the ambitious targets of achieving logistics that are essentially free of carbon dioxide (CO<sub>2</sub>) in major urban centres by 2030 and phasing out the use of conventionally fuelled vehicles in urban areas by 2050. The Transport White Paper strengthened the need to organise a more efficient interface between long-distance and last-mile freight transport, to use cleaner trucks and ITS, to limit individual deliveries to the shortest possible route and to reduce delivery times and congestion (e.g. with night deliveries). Initiative 33 of the Transport White Paper defined the strategy for near 'zero-emission urban logistics' (ZEL) around three main pillars:
- 1. producing best practice guidelines;
- 2. integrating aspects of land planning, intermodality, business practices and vehicle technology;
- 3. joint procurement for low-emission vehicles in commercial fleets.
- The 2013 Urban Mobility Package 'Together towards competitive and resource-efficient urban mobility' (European Commission, 2013b) further describes the set of supporting actions and funding opportunities focusing on the following key areas:
- manage urban logistic demand through land-use planning, the widespread use of 'service and delivery plans' and actions for bundling shipments together or shifting some deliveries to off-peak periods;
- shift certain flows to other modes, such as bicycles or boats, while creating the right framework conditions for ensuring economic viability to alternative modes (e.g. dedicated space, enforcement, privileged access, planning conditions and free parking);
- improve efficiency by a better selection of modes, improving loading/unloading facilities; or increasing the load factors and the use of ITS solutions to optimise routes, improve services and reduce costs and impacts;
- use improved vehicles and fuels that can make urban logistics quieter, safer, cleaner and more efficient.
- The 2013 Urban Mobility Package also linked the strategy for achieving near 'zero-emission urban logistics' to two other initiatives outlined in the Transport White Paper:
  - the widespread development and adoption of Sustainable Urban Mobility Plans (SUMPs) in EU cities;
  - the development of a package for urban road-user charging and access-restriction schemes.
- The Commission's Communication on e-commerce 'Stimulating growth and employment: an action plan for doubling the volume of e-commerce in Europe by 2015'

(European Commission, 2012), and other EU initiatives identified the physical delivery of goods ordered online as one of the key elements for e-commerce growth. In December 2012, the Commission published a further Communication 'Commission presents roadmap for completing the Single Market for parcel delivery' (European Commission, 2013a) to boost e-commerce in the EU, and to ensure that e-retailers and consumers have access to affordable and high-quality parcel delivery services. Among the main actions envisaged in the roadmap (e.g. increased transparency and information), some have direct impacts on parcel delivery operators, for example:

- enhanced interoperability (i.e. solutions to interconnect information systems and open interfaces to allow data exchange – notably tracking, tracing and labelling);
- solutions for more effective returns, which may also include cooperation and consolidation options with a view to reducing the costs of last-mile delivery.

Most of these EC policy targets have been transposed into current research priorities. CIVITAS 2020, as part of the EU's 'Horizon 2020' (the EU framework programme for Research and Innovation), is now the umbrella for all research and collaborative demonstrative projects addressing innovation in resource-efficient and competitive urban mobility and transport.

The first Horizon 2020 call, addressing the reduction of the impacts and costs of urban freight, was published in 2013. Four new projects started research activities in summer 2015 and will address a number of key topics that fit in the range of the above-mentioned priorities and policy targets:

- 'City Logistics in Living Laboratories' (CITYLAB) will support cities and private companies developing new services and business models for improved sustainability and profitability of their logistic activities.
- 'New Cooperative Business Models and Guidance for Sustainable City Logistics' (NOVELOG) will enable city logistics policy formulation and decision-making as part of the city's sustainable urban mobility planning, and support implementation and take-up of appropriate measures.
- 'Sustainable Urban Consolidation CentrES for conStruction' (SUCCESS) will improve knowledge and understanding of freight distribution and service trips for the construction sector, and demonstrate impacts in terms of transport and environmental efficiency.
- Rethinking Urban Transportation through advanced tools and supply chain collaboration (U-TURN) will identify opportunities for collaboration and innovative logisticssharing strategies, and showcase their impact and results.

The 2016-2017 Horizon 2020 topics will expand the CIVITAS initiative by opening three challenge-based research and/or innovation topics.

In January 2015, the 'Urban Freight Research Roadmap' was launched by ERTRAC-ALICE (ERTRAC, n.d.). As a result of an extensive consultation and the contribution of experts from all important stakeholder groups involved in urban freight operations and research activities, the Roadmap identifies a set of priorities for the definition of research programmes, including Horizon 2020.



#### 3.2.3 Research activities and outcomes

The review of research activities and outcomes in urban freight transport is based on a selected list of 20 projects available from TRIP plus some additional projects analysed from national research and other initiatives listed in Annex 2 of the 'Urban Freight Research Roadmap'.

Projects and activities have been clustered into the following research areas:

- vehicles and fuels;
- load units and intermodality;
- infrastructure;
- ITS;
- policies and stakeholder involvement.

In the following sections, each of these areas are addressed in turn, covering:

- a brief description of the topics that characterise research in the area;
- · recommendations for the direction of future research;
- · results of the review analysis.

#### 3.2.3.1 Vehicles and fuels

Research projects in this field are mainly focused on two major issues:

- the development and use of eco-friendly vehicles (intended as clean, low pollutant or low noise emissions) to reduce the negative impacts related to goods deliveries and to enhance liveability in cities, especially in inner urban areas;
- the testing and piloting of flexible vehicles to improve the efficiency of deliveries by increasing load factors and by making vehicles adaptable to different types of goods and loads.

Research focused on solutions for:

- measuring and reducing emissions, as in the projects 'Green Heavy Duty Engine' (GREEN, 2005-2008) and 'Particulates, Freight and heavy duty vehicles in Urban Environments' (PARFUM, 2006-2009);
- providing a methodology to calculate and monitor carbon emissions, as in the project 'Carbon Footprint of Freight Transport' (COFRET, 2011-2013);
- setting standards and a certification scheme for vehicles and equipment operating under 60 dB (A) for use in night-time deliveries (mentioned on page 18).

Relevant achievements in relation to clean vehicles were also realised by projects prototyping new vehicles. The French project 'MEdium duty & LOw emission for DYStribution' (MELODYS, 2009) demonstrated, in real conditions, the use of three medium-size truck prototypes (13 tonnes to 16 tonnes) in full electric (FE) mode and FE + range extender mode. The 'Design of Electric LIght Vans for Environment-impact Reduction' project (DELIVER, 2011-2015) developed a light commercial electric vehicle (EV) that had a dedicated design to raise efficiency by 40 % compared with conventional vehicles, which are typically derived from passenger cars or pick-up trucks. The prototype vehicle that was tested in summer 2014 showed that new ideas can be adopted by vehicle manufacturers to improve the next generation of electric vehicles<sup>3</sup>.

The CycleLogistics project (2011-2014) aimed to reduce the energy used in urban freight transport by replacing motorised vehicles with cargo bikes for intra-urban delivery and goods transport in Europe. It showed that the use of cargo bikes can replace about 25 % of the movement of goods in urban areas. On the promising results of this project, the follow-up project 'CycleLogistics Ahead' started in 2014.

The 'Freight Electric Vehicles in Urban Europe' project (FREVUE, 2013-2017) is trying to fill the many gaps in technological and operational performance of freight electric vehicles, which often constrain private operators in their decision to buy a vehicle. This research project focuses on assessing the use of electric freight vehicles in city logistics – 127 vehicles ranging from 3.5-tonne vans to 18-tonne trucks. The early-stage results show that vehicle manufacturers were often not able to provide responsive maintenance services, so leading to vehicles being out of order for unacceptable periods of time.

#### 3.2.3.2 Load units and intermodality

One of the most critical issues related to urban freight transport is that load factors can be low, leading to the inefficient use of fuel and road space.

The 'Sustainability and Efficiency of City Logistics' project (CITYLOG, 2010-2012) addressed precisely this topic and proposed some potential solutions through innovative load units, which can be redesigned to operate on different missions. In practical terms, CITYLOG developed and tested a set of complementary vehicles: a high-capacity heavy-medium truck to operate as a 'freight bus' to carry several specifically designed load units that can be transferred to different distribution vans for last-kilometre delivery. The design is based on compact containers with extensible legs for easy shipment without the need for cranes or complex actuators on the vehicles, and no special equipment in the depots or in the public areas. CITYLOG also developed the 'bento-box' concept – a modular pack station with removable trolleys. A reconfigurable internal layout enables different uses, either as a simple container or mobile pack station.

<sup>&</sup>lt;sup>3</sup> Further research is in any case needed to analyse whether the performance and usability in real fleet operation need to be approved before a production design can be derived from the concept design presented.

CITYLOG successfully demonstrated the desynchronisation of the delivery process between operators and final customers to reduce unsuccessful deliveries and increase the load factor.

The CITYLOG outcomes demonstrate how further research that builds on the experience of previous projects can lead to better results. For example, the 'Innovative distribution with intermodal freight operation in metropolitan areas' project (IDIOMA, 1998-2001) highlighted some technical problems in testing city/small container concepts. IDIOMA suggested the need for more standardisation efforts and further demonstration projects in developing small containers/innovative load units. It also stressed the importance of:

- linking this topic to infrastructure and equipment;
- sharing and using information along the entire supply chain, and on transhipment systems to make smallvolume terminals and small load units more profitable.

Similar recommendations also came from the project 'Promote Innovative Intermodal Freight Transport' (PROMIT, 2006-2009), it stressed specifically the importance of standardisation of physical infrastructure and equipment for facilitating intermodal transport.

#### 3.2.3.3 Infrastructure

Some trends that characterise our daily lives are also increasingly affecting the urban logistics system – this is the case of the consistent growth of e-commerce leading to more parcel deliveries that mainly demand flexibility in time and location. It also leads to a requirement for different logistics facilities with different sizes and purposes (i.e. e-fulfilment centres, inner city local depots, micro-consolidation centres, but also pick-up points such as nearby shops or on-street lockers) (Lassalle, 2013).

Several research and demonstration projects have focused on the concepts of bundling or consolidating deliveries in urban consolidation centres (UCC) and of providing dedicated on-street infrastructure facilities such as loading bays, central buffer zones and proximity areas.

The CIVITAS Initiative and a number of projects such as 'Transferability of Urban Logistics Concepts and Practices from a World Wide Perspective' (TURBLOG, 2011), 'Best Practice Factory for Freight Transport' (BESTFACT, 2012-2015), 'Sustainable MARketdriven Terminal Solutions for Efficient freight Transport' (SMILE, 2009), 'Last Mile Logistics' (LAMILO, 2011-2015) and 'Sustainable MARketdriven Terminal Solutions for Efficient freight Transport' (SMARTSET, 2013-2016) provide several examples of measures developed in conjunction with a dedicated public policy (e.g. private-public partnership (PPP) for managing an urban consolidation centre, while introducing access restrictions in city centres) or specifically devoted to improve the infrastructure and operational elements of terminals and facilities.

#### 3.2.3.4 ITS

ITS can offer a wide package of services to improve the overall efficiency of goods distribution. This ranges from access control and privileges granted to specific vehicles (low noise, and low or zero emissions) to dynamic routing, lane sharing, load index control and delivery space availability information related to logistics. The number of projects dealing with ITS themes is constantly increasing, which increases the number of innovative solutions being proposed. The real challenge is to identify the options with high transferability to maximise the effects of research.

For example, the Cooperative Mobility Systems and Services for Energy Efficiency project (eCoMove, 2010-2013) aimed to develop core technologies and applications based on vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, where vehicle eco-relevant data can be shared in real time with other vehicles and traffic controllers as a basis for fuel-efficient driving support and traffic management.

Another ongoing project, CO-GISTICS (2014-2017), is deploying different kinds of cooperative ITS services for urban freight logistics (such as intelligent parking and delivery areas (optimisation of vehicles' stops along their route and of delivery of goods in urban areas) and eco-drive support (support for truck drivers in adopting a more energy efficient driving mode and reducing fuel consumption and CO<sub>2</sub> emissions)).

The project 'Intelligent Cargo in Efficient and Sustainable Global Logistics Operations' (iCARGO, 2011-2015) aimed to advance and extend the use of ICT to support new logistics services that:

- synchronise vehicle movements and logistics operations across various modes and actors;
- adapt to changing conditions through dynamic planning methods involving intelligent cargo, vehicle and infrastructure systems;
- combine services, resources and information from different stakeholders, taking part in an open freight-management ecosystem.

To achieve the above-mentioned targets, iCargo designed and implemented a decentralised ICT infrastructure that allows real world objects, new planning services (including CO<sub>2</sub> calculation capabilities) and existing systems to co-exist and efficiently cooperate at an affordable cost for logistics stakeholders.

Another project in this field is 'smart freight transport in urban areas' (SMARTFREIGHT, 2008-2010). The results of this project are relevant to updated traffic information and dynamic traffic management strategies for freight operators and loading bay management. The project explored the offering of booking systems, dynamic access and priority offers to freight vehicles depending on their properties and the traffic situation, together with monitoring of selected freight vehicles.

#### 3.2.3.5 Policies and stakeholder involvement

Though sometimes underestimated and disregarded, the role of active stakeholders within the decision process of implementing new solutions for sustainable urban freight transport has proved to be of crucial relevance for successful policy achievements.

During the first three editions of the CIVITAS Initiative programme between 2002 and 2012, a good part of the several urban freight logistics measures that were tested<sup>4</sup> had a high failure rate. Apart from contingency reasons in some cases (e.g. the poor availability of clean compressed natural gas (CNG) trucks in the early 2000s) most of the delays and failures were due to an incorrect approach to involving private companies, lack of their support and resistance from other stakeholders. Better results achieved by more recent CIVITAS measures have demonstrated that private stakeholders (local businesses and delivery companies) should be involved while planning the initiatives to establish common objectives and to avoid possible unfair competitive advantages. Indeed, many of these policy measures strongly rely on the cooperation of private companies, which often take the risk of making their logistics operations less efficient and more costly (van Rooijen & Quak, 2014 and 2010).

The approach followed by the 'ENergy efficiency in City LOgistics Services for small and mid-sized European Historic Towns' project (ENCLOSE 2012-2013) to tackle this issue was the promotion of comprehensive Sustainable Urban Logistic Plan (SULP) guidelines specifically targeted to European small/midsize historic towns. In addition, the Clean Last mile transport and logistics management for smart and Efficient local Governments in Europe (C-LIEGE, 2011-2013) project analysed the role of city logistics managers and developed local freight development plans (LFDPs) in the partner cities.

The 'Transport and Innovation Logistics by Local Authorities with a Zest for Efficiency and Realisation' project (TRAILBLAZER, 2010-2013) analysed and demonstrated the fundamental role of delivery and servicing plans (DSPs) for improving city logistics from an operational point of view and from the perspective of the sender/receiver of the goods (public entities, businesses, retailers, etc.). DSPs are essentially the equivalent of workplace travel plans for freight. They can also be very effective for policy-making when applied to a district (i.e. area-wide DSPs) or a specific supply chain (e.g. food distribution).

Another project that devoted attention to the involvement of stakeholders is 'Smart Urban Freight Solutions' (SMARTFUSION, 2012-2015). Part of the Green Car Initiative, its objective was to develop a PPP to evaluate the technical and logistical feasibility of introducing fully electric vehicles and the second generation of hybrid truck technology in last-kilometre operations. The first step of the innovative design and monitoring framework (DMF) for monitoring process was the engagement of all relevant stakeholders and discussion of the current issue: each stakeholder indicated his/her interests, perception

of problems, available resources and mandates. The DMF process in piloting sites was highly interactive and managed to incorporate different views, creating strong commitment among the actors and disseminating the project successfully to the local community.

#### 3.3 Urban intelligent transport systems

#### 3.3.1 Preliminary recommendations

A large amount of research focuses on the area of ITS. Recommendations from this analysis are to prioritise the following areas for future research:

 Suitable business models for providing highly personalised, reliable and useful information on traffic safety and convenience services at a price that users are willing to pay. The European Commission's Urban ITS Expert Group (EC 2013c) recommends that the public sector takes action and implements multimodal ITS services in case the private sector is not able to develop viable business models.



- As identified by the Close communications for cooperation between cybercars (CyberCars-2, 2008) project, the merger of driverless vehicles and advanced driver assistance systems is on-going. Research and regulations on future autonomous driving systems thus need to ensure that the transition from current driver assistance systems to the advanced systems is smooth, with a constantly increasing, level of automation.
- The individual end user is key to successful ITS projects (Urban ITS Expert Group, EC 2013e). However, irrespective of the mode of transport, a problem not solved by ITS applications for the end users so far is the level and the personalisation of information provision. To impact user behaviour in a certain way, different users need to be addressed in different ways. Respective psychological research (e.g. in combination with response to hazardous events) could be covered by future research programmes.



 A large number of studies have proposed concepts of smart urban logistics with freight distribution centres. To date, their impact on real-life freight services in agglomerations is limited. Research should be performed on the drivers, barriers and business models for intercompany cooperation on urban territories. A large-scale implementation with a city fully supporting and fostering a smart and cooperative urban freight system would be needed for demonstrating its feasibility and impacts. ITS traffic management systems can help to support urban logistics, and to reconcile them with targets of environmental policy and the quality of urban living (Urban ITS Expert Group, EC 2013e).

Other recommendations include:

- Political initiatives may be required to develop a wider and innovative 'Pan-European Regulation' to overcome the discrepant and diverging national approaches in enforcement of ITS standards.
- Investigate the potential for developing a common European standard to replace the numerous national standards that have been developed for interoperable public transport systems, added value ticketing, payment and added value services – including multimodal transport systems. Binding standards at an EU level would ease the use of public transport and multimodal mobility services for international travellers (see also the recommendations of the Urban ITS Expert Group, EC 2013c on standardisation and EC 2013d on the availability and benefits of open international standards or the need to integrate ticketing and multimodal journey planning).
- The data privacy aspects, payment allocations and the role of organising bodies with regard to international use of public transport ticketing systems should be clarified. This area of research should cover customer satisfaction, equity, and institutional and market organisation issues rather than pure technical or economic issues (Urban ITS Expert Group, EC 2013d).
- To gather and consolidate experiences with the various ITS system levels and configurations, and to disseminate these among cities, further demonstration projects may be required at the European and national level. Findings and recommendations should be systematically evaluated during and immediately after the demonstration cases to feed into followup activities without major delays. Existing platforms and programmes, including CIVITAS, may serve as coordinating and data clearing institutions.
- The implementation of multimodal ITS systems is often an organisational and institutional problem rather than a technical problem. Research should thus explore how to foster cooperation between the various bodies in urban areas (Urban ITS Expert Group, EC 2013e).

#### 3.3.2 Research environment and development

Under this sub-theme, 20 research projects were analysed – 19 were financed by various European programmes and one by a national programme. Table 3-3 summarises projects included in this analysis, their duration and source of funding.

#### 3.3.2.1 Overall direction of research

Collisions and congestion constitute the main drivers for the development and implementation of ITS in road transport. In previous, framework programmes, this topic has been on the research agenda of the EU, its Member States and international bodies, such as the World Road Association (PIARC).

#### Project acronym **Project name** Project duration | Source of funding INVETE Intelligent In-Vehicle Terminal 01/2000-05/2002 FP5 - IST - KA1 - Systems and services for the For Multimodal Flexible Collective citizens Transport Services STARDUST Towards Sustainable Town 03/2001-05/2004 FP5 EESD KA4 - City of Tomorrow and Cultural development: A Research on Heritage Deployment of Urban Sustainable Transport GST Global System for Telematics 03/2004-04/2007 FP6-IST - Information Society Technologies -Priority Thematic Area 2 (PTA2) HIGHWAY Breakthrough Intelligent Maps and 04/2004-12/2006 FP6-IST - Information Society Technologies -Geographic Tools for the Context-Priority Thematic Area 2 (PTA2) aware Delivery of E-safety and Addedvalue Services MODURBAN FP6-SUSTDEV-2 – Sustainable Surface Transport Modular Urban-guided Rail Systems 01/2005-12/2008 FAIR Fully Automatic Integrated Road 01/2005-06/2006 FP6-IST - Information Society Technologies -Control Priority Thematic Area 2 (PTA2) INTRO Intelligent Roads 03/2005-02/2008 FP6-SUSTDEV-3 – Global Change and Ecosystems CYBERCARS-2 Close Communications for Cooperation 01/2006-12/2008 FP6-IST - Information Society Technologies between Cybercars Priority Thematic Area 2 (PTA2) REPOSIT Relative Positioning for Collision 01/2006-12/2007 FP6-IST - Information Society Technologies -**Avoidance Systems** Priority Thematic Area 2 (PTA2) SAFESPOT Cooperative Systems for Road Safety 02/2006-01/2010 FP6-IST - Information Society Technologies -Priority Thematic Area 2 (PTA2) COOPERS Co-operative Networks for Intelligent 02/2006-01/2010 FP6-IST - Information Society Technologies -**Road Safety** Priority Thematic Area 2 (PTA2) SIMBA Transforming Road Transport through 03/2006-03/2008 FP6-SUSTDEV-3 - Global Change and Worldwide Cooperation Ecosystems CVIS Cooperative Vehicle-Infrastructure 07/2006-06/2010 FP6-IST – Information Society Technologies – Priority Thematic Area 2 (PTA2) Systems HEAVYROUTE Intelligent Route Guidance of Heavy FP6-SUSTDEV-2 – Sustainable Surface Transport 09/2006-02/2009 Vehicles CHINOS Container Handling in Intermodal 10/2006-05/2010 FP6-SUSTDEV-2 – Sustainable Surface Transport Nodes – Optimal and Secure Telematics in public 11/2007-02/2008 Czech Republic – MDCR – Support of Sustainable Field of passenger check-in systems Transport Development Implementation transportation SMARTFREIGHT Smart Freight Transport in Urban Areas 01/2008-06/2010 FP7-ICT – Information and Communication Technologies HAVEit Highly Automated Vehicles for 02/2008-06/2011 FP7-ICT – Information and Communication Intelligent Transport Technologies WISETRIP Wide Scale Network of E-systems 02/2008-11/2010 FP7-TPT - Transport (Including Aeronautics) for Multimodal Journey Planning and Horizontal activities for implementation of the Delivery of Trip Intelligent Personalised transport programme (TPT) Data

#### Table 3-3 Projects identified for urban intelligent transport systems sub-theme

Project acronym	Project name	<b>Project duration</b>	Source of funding
SMART RRS	Innovative concepts for smart road restraint systems to provide greater safety for vulnerable road users	11/2008-05/2012	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
CONDUITS	Coordination of Network Descriptors for Urban Intelligent Transportation Systems	05/2009-04/2011	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
CITY MOVE	City multi-Role Optimised Vehicle	01/2010-12/2012	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)

#### Table 3-3 (continued) Projects identified for urban intelligent transport systems sub-theme

Among the top-priority topics identified for cooperation were electronic toll collection, ITS for public transport and integrated traffic management. Thus, non-road and multimodal applications form important development fields for ITS solutions.

Since the late 1990s, auto manufacturers and researchers have been exploring V2V and V2I communication systems collectively known as vehicle to everything (V2X)) in combination with intelligent road infrastructure. Within FP6, the emphasis was on the definition of data and communication protocols. In FP7 and parallel national endeavours, the focus has been more on practical applications, including the possibilities provided the Galileo programme for end users and road managers. In part, the technologies have become the common standard, such as floating car data (FCD) used by contemporary navigation systems. However, in the case of V2V and V2I communication systems, research intensity has reduced due to the options provided by modern broadband mobile communication standards and video surveillance.

Given the great attention that autonomous driving has received to date, the three projects identified under this topic in TRIP seem to be few. But the collection shows that already in the early 2000s the topic was on the research agenda. The first prototypes were on the test tracks in Europe starting in 2008. For public transport systems, ITS can mean smarter user services or the more efficient and intelligent way of operating public transport and multimodal systems. An overview of the state of intermodality and public transport services was provided by the project 'A Knowledge Base for Intermodal Passenger Travel in Europe' (KITE, 2009).

Referring to previous FP7 projects outside the urban environment, the issues of personalising information and the commercial viability of ITS solutions for transport safety has recently been brought up. Although there is a user demand for highly personalised, reliable and useful information on traffic safety and convenience, the willingness to pay for such products seems to be extremely limited. Suitable business models across the value chain should be explored by future research.

#### **3.3.2.2** Trends and policy requirements

One of the major trends that can be seen is the migration of research topics from centrally controlled or supervised V2V and V2I systems to autonomous systems. Contemporary sensor

technologies and computing powers on board vehicles allow this shift, which saves enormous investments in infrastructure installations. Some research challenges emerge:

- CyberCars-2 (2008): The merger of driverless vehicles and advanced driver assistance systems is considered a key challenge for future research.
- Highly Automated Vehicles for Intelligent Transport (HAVEit, 2011): the verification and the level of use with respect to information received 'from outside' (V2V and V2I communication). Such information would significantly increase the perception horizon of highly automated vehicles, but will also raise additional questions on responsibility, timeliness, usefulness and the potential misuse of the information.
- FAIR (2010): A wider and innovative 'Pan-European Regulation' is needed to overcome the discrepant and diverging national approaches in enforcement of ITS standards. Here, a major political initiative is required.

For ITS in multimodal and public transport services, the gaps to be filled by future research – and policy action – are larger than in the road sector:

- Numerous national standards and implementations on interoperable public transport systems have existed since the late 2000s. However, some Member States are still searching for a common national standard for added value ticketing, payment and added value services. The latter includes multimodal transport systems. Binding standards at the EU level would certainly ease the use of public transport and multimodal mobility services for international travellers.
- Prominent examples of existing standards, but with significant barriers to their implementation, are the European train control system (ETCS) and the nextgeneration air traffic control systems to implement the single European railway area and the single European sky.
- Clarifications are needed on data privacy, payment allocations and the role of organising bodies. This area of research would include equity and institutional and market organisation issues rather than pure technical or economic issues.

Irrespective of the mode of transport, a problem not solved by ITS applications for end users so far is the level and the personalisation of information provision. To impact user behaviour in a certain way, different users need to be addressed in different ways. Respective psychological research (e.g. in combination with response to hazardous events) could be covered by future research programmes.

In the 1980s and 1990s, a large number of studies proposed concepts of smart urban logistics with freight distribution centres. However, their impact on real-life freight services in agglomerations was limited. A number of studies still deal with the topic. However, what seems to be missing is work on the drivers, barriers and business models for inter-company cooperations in urban areas. Besides the necessarily small test fields in the past research, a large-scale implementation with a city fully supporting and fostering a smart and cooperative urban freight system would be needed to demonstrate its feasibility and impacts.

## **3.3.2.3** Compliance with current policy requirements and targets

The Green Paper on Urban Mobility was published by the European Commission in September 2007 (European Commission, 2007). This document provided a broad basis for discussion between all stakeholders active in the field of urban transport in five policy fields:

- 1. free-flowing towns and cities;
- 2. greener towns and cities;
- 3. smarter urban transport;
- 4. accessible urban transport;
- 5. safe and secure urban transport.

Out of these, 1, 3 and 5 can be addressed by ITS. Most projects reviewed in this document relate to road safety (i.e. item 5). However, multimodal and public transport related applications gain increasing importance. An assessment of their findings, recommendations, synergies and specificities across Europe would be needed.

FP6 projects like 'Cooperative Systems for Road Safety' (SAFESPOT, 2010) demonstrated that many technical solutions in road-based V2V and V2I communication technologies are working. Nevertheless, more effort is required to achieve real deployment. The key to success is that all stakeholders involved in the next step of deployment should jointly offer a number of functions and services that together can create a sustainable deployment. The gaps in research have been partly filled by follow-up activities like 'Innovative concepts for smart road restraint systems to provide better safety for vulnerable road users' (SMART RRS, 2012). However, given the rapidly changing environment in mobile communication technologies, the flow of V2X communication systems needs to be reconsidered and potential add-on applications need to be defined. Recommended future work is the development of a demonstrator system using vehicles to prove simulations against real-world situations.

#### 3.3.2.4 Overlaps and synergies

Looking at the projects reviewed, there seems to be a great overlap between projects on V2V and V2I communication standards and applications. The potential synergies have been partly exploited – during its lifetime, SAFESPOT established a number of cooperation activities, in particular with the Car2Car Communication Consortium (C2C-CC), 'Communications for eSafety' (COMeSafety) and the integrated projects 'Cooperative Vehicle-Infrastructure Systems' (CVIS) and 'Co-operative Networks for Intelligent Road Safety' (COOPERS) that have been running at the same time on complementary activities. Earlier clusters embraced the 'Global System for Telematics' (GST, 2007) project and its partner activities prosys, eSafety, 3GT, Aide, Easis, E-merge, Osgi and Prevent.

Other projects could be included in networks on technology exchange if the institutional and business-related barriers could be overcome (e.g. SAFESPOT and 'Relative Positioning for Collision Avoidance Systems' (REPOSIT)). A full-scale knowledge transfer between ITS for road and the public transport sector should be the target – in particular, for passenger 'infotainment' and freight supervision applications.

Synergies exist within the 'Cybernetic Technologies for the Car in the City' (CyberCars) cluster, CyberCars 2 and 'Cybernetic Transport Systems for the cities of tomorrow' (CyberMove) of the 5<sup>th</sup> and 6<sup>th</sup> framework programmes. Cross-fertilisation of knowledge between modes on vehicle automation and guidance would help implementing roadside solutions into public transport environments.

There is a cluster of projects dealing with the optimisation of urban freight. This is SMARTFREIGHT (2010) and 'City multi-role Optimised Vehicle' (CITY MOVE, 2012) as described below. Furthermore, CITY MOVE was conceived together with the project CITYLOG and they fully complement an integrated innovative approach for urban freight distribution. In addition a number of initiatives deal with efficient and low impact urban freight solutions at a national level.



#### 3.3.3 Research activities and outcomes

## 3.3.3.1 Technology status and research achievements

Collisions and congestion constitute the main drivers for the development and implementation of ITS in road transport. In previous framework programmes, the topics have been on the research agenda of the EU, its Member States and international bodies such as PIARC. The FP6 integrated project 'Transforming Road Transport through Worldwide Cooperation' SIMBA (2008) has tried to capture the existing worldwide knowledge on successful ITS implementations and to derive lessons for Europe. The main achievement of the project is the establishment of expert networks between policy makers, industrialists and researchers, and to raise awareness for the topics within the European Commission. Among the top priority topics identified for cooperation were electronic toll collection, and ITS for public transport and integrated traffic management. Thus, non-road and multimodal applications are important development areas for ITS solutions.

Of the 126 projects identified under the Theme 'Urban Mobility' in TRIP, 18 projects with complete information have been analysed to understand research directions, the state of knowledge and results obtained in the field of urban ITS. The majority of studies deal with road (passenger) transport and safety issues, but other modes and transport fields are covered too. Accordingly, the project reviews are structured in three thematic areas: traffic management and intelligent roads for enhanced road safety; guidance and the automation of future road transport; and telematics for enhanced multimodal transport systems.

## 3.3.3.2 Traffic management and intelligent roads for enhanced road safety

Since the late 1990s, auto manufacturers and researchers have been exploring V2V and V2I communication systems in combination with intelligent road infrastructure. The concept promised forward-looking incident warning and infrastructure condition communication among all road users equipped with the technology. Via FCD collection, traffic management centres should get another valuable and cheap source of congestion measurement and traffic management for curbing congestion and controlling environmental impacts from nitrogen oxides, particles, ozone and traffic noise. A potential link between ITS systems and environmental policy was demonstrated by the FP5 project 'Healthier Environment through Abatement of Vehicle Emission and Noise' (HEAVEN).

Both of these interrelated streams of technology development have been supported intensively by European and national research programmes, including mixed funding via the 'European research area networking programme' (ERA-NET). In FP6, the emphasis was on the definition of data and communication protocols. In FP7 and parallel national research and technology development and demonstration (RTD), endeavours turned more towards practical applications including the possibilities provided by Galileo for end users and road managers. In part, the technologies have produced some common standards to date, such as FCD used by contemporary navigation systems. However, in the case of V2V and V2I communication systems, research intensity has reduced due to the options provided by modern broadband mobile communication standards and video surveillance.

The FP7 project, 'Coordination of Network Descriptors for Urban Intelligent Transport Systems' (CONDUITS), gives an overview of the technologies and policies for traffic management and ITS currently implemented by European and world cities. With support from the POLIS city network, a city pool of 39 members contributed to the assessment of requirements towards ITS and to the definition of respective key performance indicators. These indicators, communicated in a variety of fact sheets, support a forward-looking plan of the potential benefits from different ITS settings.

The FP7 project SMART RRS built on earlier RTD activities on a communication protocol definition and aimed to develop a new road restraint system (RRS) with the following attributes:

- using new materials and fixtures to absorb crash energy during collisions and minimise injury and further damage;
- providing timely and useful information to road users that will assist in the prevention of road incidents (primary safety);
- providing timely and useful information to emergency services, road authorities and other road users in the event of a road incident (tertiary safety).

The project resulted in the development of a smart road restraint system that could be incorporated within the primary safety roadside system and the tertiary safety roadside system. Innovative techniques and devices covered the fields of infrastructure-based sensing, vehicle-based sensing and communication systems.

The CVIS project aimed to develop a unified technical solution for allowing vehicles to communicate, and cooperate, directly with each other and with roadside infrastructure. It defined and validated an open architecture and system concept for a number of cooperative system applications. It also developed common core components to support cooperation models in real-life applications, together with services for drivers, operators, industry and other key stakeholders. Furthermore, it addressed issues such as user acceptance, data privacy and security, system openness and interoperability, risk and liability, public policy needs, cost/benefit and business models, and roll-out plans for implementation. A deployment - enabling toolkit and deployment roadmaps were developed. CVIS created a mobile router with multiple communication interfaces, innovative positioning techniques and supporting services for the deployment of the application. CVIS achievements were applied in test sites in seven countries across Europe. By combining data from roadside sensors and data made available from nearby vehicles, advance knowledge can be gained of potential safety risks. By communicating this knowledge to approaching vehicles, the driver is given extra time to react to these risks. One of the main aims of SAFESPOT was to develop a 'Safety Margin Assistant' that extends the safety information available to drivers 'in space and time'. This required research in the fields of accurate relative localisation, ad-hoc dynamic networking, dynamic local traffic maps, infrastructure-based sensing techniques, end-user acceptability and barriers to implementation. The project carried out reference applications and a cost-benefit-analysis.

COOPERS aimed to build upon existing equipment and infrastructure as far as possible to incorporate bidirectional infrastructure-vehicle links as an open standardised wireless communication technology. It provided vehicles and drivers with real-time local situation based, safety related traffic and infrastructure status information distributed via dedicated Infrastructure-to-Vehicle (I2V) (communications) links. This approach extended the concepts of in-vehicle autonomous systems and V2V with tactical and strategic traffic information, which could only be provided by the infrastructure operator in real time. The real-time communication link between infrastructure and vehicle can also be used for V2I communication using vehicles as floating sensors to verify infrastructure sensor data as a primary source for traffic control measures.

The 'Intelligent Roads' project (INTRO, 2010) aimed to address the problems of road safety and capacity, combining sensing technologies and local databases with real-time networking technologies. This included testing new technologies (e.g. sensor technologies and real-time warning systems), and research in sensor data analysis and users' behaviour in response to such technologies (through driving simulator studies). As a key result, INTRO developed a new method for estimating travel time from unidentified probe vehicle data. The results, based on simulated data, showed that the method generally performs better compared to the existing piecewise constant vehicle profile method. INTRO has also developed safety indicators for monitoring traffic risk.

In FP6, GST aimed to create an open and standardised end-toend architecture for automotive telematics services, improving the cost-effectiveness and thus increasing the availability of telematics services to manufacturers and consumers. GST identified the requirements of users, car manufacturers, control centre operators, middleware providers, terminal manufacturers and service providers. GST was an 'Integrated Project' or programme of interdependent activities, aiming to structure European research in the field of telematics. There were seven sub-projects, four of which were technology-oriented ('Open Systems', 'Security', 'Service Payment' and 'Certification') and the other three service-oriented ('Rescue', 'Enhanced Floating Car Data' and 'Safety Channel'). The key results were:

 definition of an overall framework architecture for open telematics across the seven sub-projects and specifications for the key interfaces;

- development of a common validation plan to ensure that the site validation results can be aggregated and compared at the project level;
- addressing relevant operational and business aspects for market introduction of open telematics.

REPOSIT aimed to address the use of relative global positioning systems and wireless V2V communications integrated with existing collision avoidance systems (CAS). The final goal of REPOSIT was to show that the use of relative GPS combined with wireless V2V communications is feasible and makes sense in the context of CAS and, in particular, for the case of longitudinal and intersection collisions. Its results were system requirements, communication algorithms and an integrated simulator for V2V communications, simulations on the scenarios, an analysis of the feasibility of in-vehicle integration, and an outline of a certification and standardisation policy.

The objective of the 'Fully Automatic Integrated Road Control' project (FAIR, 2006) was to increase traffic safety, traffic efficiency and road protection through a pragmatic approach for planning and future realisation of practical and operative solutions. Specific research issues were:

- the design and evaluation of best practice concepts in supervision, violation detection, registration and reporting for a central database;
- benefits and safety improvement of future automated concepts of road infrastructure;
- concepts for pilot installations of selected enforcement technologies;
- analysis of integration aspects and synergy within the future pilot tests.

The project analysed the potential to achieve a 'best overall solution' through the use of safety technologies to develop innovative and efficient traffic supervision, and control systems and infrastructure protection for a higher overall economy.

## 3.3.3.3 Guidance and automation of future road transport

Given the great attention autonomous driving has received to date, it is surprising that only three projects have been identified under this topic in TRIP. Nevertheless, our research shows that the topic was already on the research agenda in the early 2000s and the first prototypes have been on test tracks in Europe since 2008. All three projects developed demonstrators.

The 'Highly Automated Vehicles for Intelligent Transport' project (HAVEit, 2011) developed prototypes for highly automated cars and trucks, which successfully managed real-world test situations. A major concern of the project was the way and level that information from outside was used for safeguarding the driving process. Moreover, monitoring the driver's condition played an important role in the research. CyberCars-2 was driven by the vision that, in the near future, cybernetic transport systems (i.e. automated vehicles) will be seen on city roads and dedicated road infrastructures. Based on two previous projects, CyberCars and CyberMove (FP5), functional prototypes, communication protocols, driving algorithms and a traffic control centre were developed with a special focus on dense traffic conditions. Besides the proof of concept, the merger between driverless vehicles and advanced driver assistance systems are considered a key challenge for future research.

The aim of the project 'Breakthrough Intelligent Maps and Geographic Tools for the Context-aware Delivery of E-safety and Added-value Services' (HIGHWAY, 2006) was to enhance road safety. This was achieved by providing the driver and passengers with media interaction and with value-added location-based services, through the combination of smart real-time maps, 3G mobile technology, positioning systems and intelligent agent technology, 2D/3D spatial tools and speech synthesis/voice recognition interfaces. The prototype of the traffic information service has been successfully tested on the motorway linking the Finnish cities of Turku and Helsinki, and in the Italian city of Turin. The main HIGHWAY innovation was the integration of data from various sources with a navigable digital map for user warning and information.

Intelligent mapping, information and warning systems for road freight transport were addressed by the FP7 study 'Intelligent Route Guidance of Heavy Vehicles' (HEAVYROUTE, 2009). The study used vehicle, infrastructure and ambient conditions for intelligent pre- and on-trip information. In addition, charges and environmental constraints (noise levels, etc.) are considered for smart route information.

Including all transport modes, the project 'Wide Scale Network of E-systems for Multimodal Journey Planning and Delivery of Trip Intelligent Personalised Data' project (WISETRIP, 2010) developed a multimodal long-distance journey planner with ontrip alerts and trip change recommendations in case of disturbing or hazardous events. For this, the project built on the concepts and ideas of the HIGHWAY project. The study emphasised the personalisation of trip recommendations to narrow down the number of recommendations and thus to ease the selection process. A prototype application is available online for eight European countries.



## 3.3.3.4 Telematics for enhanced multimodal transport systems

For public transport systems, ITS can mean smarter user services or the more efficient and intelligent way of operating public transport and multimodal systems. An overview of the state of intermodality and public transport services was provided by the KITE project.

At a Member State level, the topic of enhanced user services for public transport had already been picked up by the implementation study 'Telematics in public transportation – Field of passenger check-in systems' in 2008 by the Czech Republic. The research analysed several interoperable systems running in Europe, namely in the Netherlands and in Denmark, to propose an electronic ticketing system for the Czech Republic. Besides technical and payment system issues, the identification and empowerment of an implementing organisation trusted by all market participants was crucial. Due to its neutrality and creditability, the Czech ministry for transport was selected as the organising body. Besides these early works, other countries such as Germany still work at a national solution – with no evident consideration of European standards.

The 'Modular Urban-guided Rail Systems' project (MODURBAN, 2008) turned attention - apart from more technologyoriented advances in public transport rail systems - to the cost-efficient migration to driverless systems. Similarly to the research on automation in road transport, the topic is picked up for rail systems as well. In addition, track-side and enhancements in-vehicle telematics were developed and tested. The main outputs of the project were guidelines for a 'Functional Requirements of Specifications', dealing with many technical and telematics aspects of next generation public transport systems. Innovative developments were a multi-level communication system to replace the many parallel systems in use today on trains and a train control system coping with changing technical parameters of trains over time. Some of the concepts were implemented in Metro de Madrid, Line 9.

The important field of urban freight transport was addressed by the SMARTFREIGHT project. Via mobile and dedicated short-range communication (DSRC) technology, tracking standards and operational procedures were developed to keep control of vehicle-dependent area access provisions, monitor dangerous cargo provide optimised route recommendations. Demonstrations revealed the potential of such a generic communication standard to improve safety, environment and congestion levels in urban areas.

With similar objectives, the CITYMOVE project, together with leading European vehicle manufacturers, developed an optimised vehicle and communication concept to explore the use of intermodal goods transport alternatives while minimising safety risks and environmental impacts of urban logistics.



#### 3.3.3.5 Transferability

Numerous algorithms and data standards have been developed for V2V and V2I communication. However, to date, none of these standards has become universal due to the business protection interests of the industries participating in the research and/or due to differing requirements towards, and applications of, the systems. The barriers to transferability of the solutions developed are thus high. Besides basic technical standards, such as DSRC or mobile communication protocols, common standards for vehicle and infrastructure applications of ITS are possibly obsolete with the advent of contemporary mobile communication channels.

The projects on autonomous driving were rather specific in nature – looking at details of signal processing, data exchange or driving algorithms. As a result, the detailed results are likely to have limited transferability to other vehicle or communication platforms. Nevertheless, the principal proof of technology and concept fosters the improvement of reliability and availability of self driving units on European roads. The standardisation of the behaviour of autonomous vehicles in critical situations and of liability issues are probably more urgent than the technical transferability of system components.

Concerning guided transport systems (i.e. rail and public transport), the development of the ETCS level 2, has been accomplished and has been implemented successfully on some lines of the Trans European Rail Network, in some cities and in smaller Member States. However, the standard has been implemented more widely outside the EU. Transferability of the technology, which would enhance the Single European Railway Area, is hampered by territorial market protection tendencies and investment cost considerations of Member States and their stakeholders.

#### 3.3.3.6 Policy implications

As emphasised above, the market dispersion of communication and control standards of ITS is less of a technical nature, but more driven by organisational considerations of the actors involved. Standards promise to enhance safety, user satisfaction or the competitiveness of the European transport sector. As such, policy is needed to set and enforce them. A respective area is the ETCS standard in the European rail sector. When implemented, it is often to national variations. Similar needs for enforcing standardisation exist for electronic ticketing in public transport and, in the future, for multimodal passenger information and booking systems, and intermodal freight handling.

Autonomous vehicles require policy attention. This concerns the safety and quality standards of information exchanged between vehicles, infrastructures and control centres, but also the question of responsibility if there is a collision. In case of market entry restrictions to certain network levels or test areas could help. Eventually, the question of driving licences with the use of self-driving cars or the condition of the driver needs to be addressed.

#### 3.4 Low carbon transport technologies

#### 3.4.1 Preliminary recommendations

Sustainable mobility has been on the agenda of the European Commission since the early 1990s. After initiating standards for low emissions for road vehicles and the ratification of the Kyoto protocol in 1998, the rapid rise of the global markets in 2005 turned political attention more towards capacity management issues. Then, following the economic crisis in 2008 the European Commission launched the 'Green Car Initiative' (European Commission, 2015b) recovery programme, which aimed to help return the EU to a sustainable pathway by fostering research, demonstration and implementation of low emission vehicle technologies and infrastructure. RTD efforts were supported by regulations and incentive programmes on strategy development and on fostering the use of biofuels, hydrogen and electric vehicles (European Commission 2009, 2011, 2013b, 2014, 2015). Besides the European Commission's green paper on urban development and the Transport White Paper, technical platforms such as the European Road Transport Research Advisory Council (ERTRAC, 2015) supported the definition of research needs and directions

In this section, we review 10 projects on urban mobility that are related to the sub-theme of clean vehicles. The areas covered relate mainly to electric and fuel cell propulsion technologies. Our recommendations on potential further research directions include:

- Develop technology-neutral implementation strategies. Looking at the multiple changes in technology options encouraged by the European Commission in the past two decades - from electric propulsion in the early and mid-1990s to hydrogen and biofuels and then back to electromobility indicates that pushing particular energy technologies might alienate fuel and vehicle industries. Therefore, incentives for low carbon technologies should focus on the potential and the actual benefits of various technology options rather than on technology-related performance indicators, such as the share of electric cars or the amount of hydrogen or biofuels in vehicle fuel mixes. Clean vehicles are only one part of the solution towards a low impact transport system. The challenge to be taken up by future research is to form general and goal-driven incentive systems which, despite the high level of complexity, provide clear guidance for transport users, transport suppliers, vehicle manufacturers and fuel producers on which way to go.
- Foster information dispersion. Through the numerous European Commission and national research and demonstration activities, in particular involving the city networks CIVITAS, POLIS, Cities for Mobility and ICLEI etc., a broad set of experiences has been generated. These need to be disseminated to other European (and global) cities.

 Continue working on technical challenges. Despite the several research and demonstration programmes on fuel cell technologies and electric cars, there remain technical barriers and pitfalls to be addressed. This is particularly the case for hydrogen production and transport, and battery technologies, but is also for lightweight materials and vehicle architectures. Bringing costs down while increasing robustness and availability are the big challenges for the decades ahead.

In this sub-theme, the assessment concentrated on research contributing to the reduction of greenhouse gas (GHG) emissions, as this is one of the most pressing outstanding environmental issues. Other emissions, such as air pollutants and noise, have been more prominently treated in national projects. While air pollutants are often related to GHG emissions, particulate emissions and noise seem to constitute a neglected problem, which deserves closer attention in future research programmes.

#### 3.4.2 Research environment and development

Under this sub-theme, eight research projects were analysed: all of them were financed by various European programmes. Table 3-4 summarises projects included in this analysis, their duration and source of funding.

Project acronym	Project name	<b>Project duration</b>	Source of funding
UTOPIA	Urban Transport: Options for Propulsion Systems and Instruments for Analysis	01/1998-06/2000	FP4 – TRANSPORT RTD – Transport Research and Technological Development
ZERO REGIO	Lombardia & Rhein-Main towards Zero Emission: Development and Demonstration of Infrastructure Systems for Hydrogen as an Alternative Motor Fuel	11/2004-05/2010	FP6-SUSTDEV-1 – Sustainable Energy Systems
HYCHAIN MINI-TRANS	Deployment of Innovative Low Power Fuel Cell Vehicle Fleets To Initiate an Early Market for Hydrogen as an Alternative Fuel in Europe	01/2006-01/2011	FP6-SUSTDEV-1 – Sustainable Energy Systems
CLEAN DRIVE	Clean Drive – A campaign for Cleaner Vehicles in Europe	04/2010-04/2013	IEE
ELVA	Advanced Electric Vehicle Architectures	12/2010-05/2013	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
WIDE-MOB	Building blocks concepts for efficient and safe multiuse urban electrical vehicles	12/2010-05/2014	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
EM-SAFETY	EM safety and Hazards Mitigation by proper EV design	05/2011-01/2014	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
ELCAR	E-Mobility Life Cycle Assessment Recommendations	02/2012-02/2013	FP7-ENVIRONMENT – GC.ENV.2011.3.1.3-2

#### Table 3-4 Projects identified for low carbon transport technologies sub-theme

#### 3.4.2.1 Overall research direction

Under the theme 'urban transport', two alternative fuel technologies have been supported by European Commission funding since the 4<sup>th</sup> RTD framework programme – hydrogen and fuel cell technologies, and electric vehicle technologies. In both cases, technical development and implementation issues have been researched, and demonstration projects have been carried out. However, the detailed directions of the two streams of technology differ somewhat. While hydrogen and fuel cell projects were characterised by approaching the remaining technical barriers, electromobility projects tend to focus more on finding suitable application markets.

Biofuels and more efficient conventional combustion engines have been addressed by the framework programmes, but do not directly relate to urban transport, so are not included in this review. The underlying reason for treating these propulsion technologies differently is their application area. While biofuels and more efficient combustion engines do not alter the way we need to think about mobility, the restrictions associated with electric and fuel cell vehicles do. Their shorter range or the low availability of fuelling stations, at least at present, restrict these technologies to urban areas or to a limited range.

#### 3.4.2.2 Trends over time and knowledge gaps

According to CUTE, the large-scale demonstration project, hydrogen technologies are not yet sufficiently mature to be competitive without public support. Lead markets should be established through appropriate incentive structures. From 2005, the engagement of research funding in hydrogen and fuel cell technologies paused, as attention turned more towards battery electric vehicles. However, following the announcement by several vehicle manufacturers that they were rolling out commercial models of fuel cell vehicles after 2010 and after successful applications of the fuel cell technology in urban bus transport, the fuel cell and hydrogen (FCH) joint undertaking by the European Union and industries picked up the topic once more. Most of the funded projects dealt with technical aspects of hydrogen production, transport and storage, and the efficiency, safety and durability of fuel cells. In the mobility sector, the programme followed two streams of work:

- the applicability and efficiency of hydrogen technologies in public transport is demonstrated and disseminated to local public transport companies by the projects 'Environmentally Friendly, Efficient, Electric Motion' (3EMOTION, 2015-2018), 'European Hydrogen Transit Buses in Scotland' (HyTransit, 2013-2017), 'Cities speeding up the integration of hydrogen buses in public fleets' (High V.LO-City, 2012-2018) and 'Clean Hydrogen in European Cities' (CHIC, 2010);
- demonstrators for individual passenger and freight mobility by small vehicles, cars and delivery vehicles were put on European city roads by the projects 'Hydrogen for Innovative Vehicles' (HYFIVE, 2014-2017), 'Small 4-Wheel fuel cell passenger vehicle Applications in Regional and Municipal transport' (SWARM, 2012-2017), 'Hydrogen Transport in European Cities' (HyTEC, 2011-2015), 'Preparation for Large-Scale vehicle Demonstration in

Europe; Supporting action to prepare large-scale hydrogen vehicle demonstration in Europe' (NextHyLights, 2010) and H2moves Scandinavia (2010).

As these projects are still running (except for NextHyLights and H2moves Scandinavia), final conclusions are not yet available. However, it is to be expected that the majority of European cities, public transport operators, companies and citizens can only be convinced of the maturity of the technology by several demonstration cases.

Costs, driving range and complexity of use all constitute barriers for several alternative fuel concepts, including electric vehicles. However, besides some good practice examples, it is still not clear how such incentives should be designed to maximise impact and to minimise side effects on other policy goals. Fundamental research of drivers, barriers, risks and opportunities of different incentive structures with respect to the great differences in European cities and regions is still lacking.

A design manual for new electric vehicles was developed by the project 'Advanced Electric Vehicle Architectures' (ELVA), which was then used by subsequent studies. These follow-up activities picked up a number of topics not considered in full detail by ELVA, such as advanced material applications and increased safety of alternative powered vehicles. Respective projects include: 'Safe Small Electric Vehicles through Advanced Simulation Methodologies' (SafeEV), 'Enhanced Lightweight Design' (ENLIGHT), 'Advanced High Volume Affordable Lightweighting for Future Electric Vehicles' (ALIVE) and 'Modelling And Testing for Improved Safety of key composite StructurEs in alternatively powered vehicles' (MATISSE), which together are forming the so-called SEAM cluster. Other relevant research directions to be covered by the European Commission's Green Car Initiative include:

- modularisation in the electric drive train;
- interaction of urban mobility with certain vehicle concepts;
- reduction in road injuries and fatalities with different kinds of propulsion technologies.

For hydrogen vehicles, there is still a cost and a fuel efficiency problem to be solved. In particular, concerning public transport vehicles (buses), which are most suitable for this technology, research cannot be funded by vehicle manufacturers alone. Setting appropriate incentives for favourable market conditions, such as stimulation through the EU energy taxation rules, thus remains a research and demonstration challenge across all alternative fuel and propulsion technologies. Moreover, some technical issues remain around hydrogen production, including:

- durable and low-cost materials for hydrogen electrolysers;
- reducing costs of lightweight tanks.

#### 3.4.2.3 Relation to current policy targets

Alternative propulsion technologies carry many hopes for greener, smarter and safer transport with less impact on third parties and on the environment. In the first place, the latter relates to the reduction of noise, air pollutants and GHG emissions. The 2011 White Paper 'Roadmap to 2050' of the European Commission directly addresses emission-free vehicles as the only means of individual motorised travel to be permitted in European cities by 2050, helping to achieve a 60 % GHG emission reduction. Some Member States have formulated similar emission reduction targets (e.g. the UK), targets on fossil fuel independence (e.g. Sweden), on the share of renewable fuels (European Commission and many Member States) or directly on the number of electric cars in use (e.g. Germany).

At the global level, the leaders' declaration of the G7 summit in June 2015 in Germany emphasised a low carbon pathway supported by the leading industrial players. With reference to Intergovernmental Panel on Climate Change (IPCC) and United Nations Framework Convention on Climate Change (UNFCCC) recommendations, a reduction in global carbon emissions of between 40 % and 70 % is recommended. In 2015 the European Commission proposed legislation reflecting these recommendations for Europe through the Europe 2030 climate strategy. Across all sectors, a cut of GHG emissions is expected of 43 % in Emissions Trading System (ETS) sectors and of 30 % in non-ETS sectors by 2030 relative to 1990 levels. Transport is not mentioned in detail by the declaration, but with a share of around 30 % of global GHG emissions, most of which stem from road traffic, and with reference to the statement 'curbing mobility is not an option' from the European Commission White Paper, clean cars, buses and trucks are essential to achieve these visions.

Other goals of European, national and local policies are not directly supported by replacing conventionally fuelled vehicles with alternative powered vehicles. These goals are:

- green cities with usable space for citizens;
- congestion relief;
- transport safety;
- the accessibility of transport systems by all, in particular by the growing community of elderly and mobility-restricted citizens.

However, as alternative vehicles – namely electric cars – allow the consideration of mobility in a different way, new vehicle and propulsion concepts could have an indirect impact on mobility cultures. Moreover, rethinking road vehicles in terms of propulsion technologies and vehicle architectures can open doors for further innovations, helping to approach the goals stated above.

By 2020, the EU aims to have 10 % of the transport fuel of every EU country come from renewable sources, such as biofuels. These include electricity and hydrogen generated from renewable sources. The targets and conditions are laid down in the EU's Renewable Energy Directive (EU, 2009). A related cornerstone of EU sustainability policy is the emission targets for new cars sold in the European Union. These are set at an average of 130 g  $CO_2$ -equivalent per km as of 2015 and 95 g/km as of 2021 (EU 2014). Fostering the use and deployment of fuel cell and electric vehicles directly supports this legislation.

#### 3.4.2.4 Overlaps and synergies of projects

A successful model of cooperation and spreading good practices among European cities are the various city networks. These include the CIVITAS (I, II, PLUS and FRANCOPHONE), the POLIS activities (funded by the European Commission), ICLEI (funded with UN support) and the Cities for Mobility supported by the car industry. These networks not only enhance the spread of clean vehicle implementation strategies, but are supportive for other urban mobility and development goals by exchanging experiences, raising awareness and fostering stakeholder and public participation.

Some of the projects reviewed develop similar results and tools. This holds in particular for the stream of assessment related projects, starting with 'Urban Transport: Options for Propulsion Systems and Instruments for Analysis' (UTOPIA, 2000), and including 'E-Mobility Life Cycle Assessment Recommendations' (ELCAR, 2013) and 'EM safety and Hazards Mitigation by proper EV design' (EM SAFETY, 2014). However, over 15 years, the assessment methods and data availability for the assessed technology have changed, so that reviewing and extending evaluation studies makes good sense.

For electric vehicle technologies, the SEAM project cluster which has emerged from the ELVA project, appears to be a powerful research cooperation, going into much detail for specific aspects of electric and other alternative fuel vehicles. This could serve as a continuous vehicle for cooperation between research entities and industries. The issue of patents on specific technologies held by some projects (or project partners) in this respect needs a critical review.

Implementation and demonstration projects are largely run by national bodies directly or via the ERA NET programme under the coordination of the European Commission. In the case of electric vehicles, this devotion of research and demonstration funding to the national level makes sense as it is less about the technology to be developed, but rather the fitting of EVs into regional mobility management concepts. However, the exchange of experiences related to implementation and operational issues needs coordination and support on the European, if not on the global scale.

Hydrogen and fuel cell technologies have been tested and demonstrated by several dozen projects costing over EUR 150 million. Projects funded under FP5, FP6 and FP7 included CUTE (as the largest and leading activity in this field), 'Deployment of Innovative Low Power Fuel Cell Vehicle Fleets To Initiate an Early Market for Hydrogen as an Alternative Fuel in Europe' (HYCHAIN MINI-TRANS, 2011) and 'Lombardia & Rhein-Main towards Zero Emission: Development and Demonstration of Infrastructure Systems for Hydrogen as an Alternative Motor Fuel' (ZERO REGIO, 2010). As electric and hybrid propulsion technologies have gained ground after the fuel cell demonstrations reported considerable cost issues, the demonstration phase paused in the second half of the 2000s. However, as progress in extending battery capacity for vehicles slowed down and several leading vehicle manufacturers announced fuel cell models between 2010 and 2015, the FCH restarted technology development and large demonstration programmes for buses, small vehicles, cars and vans.

Vehicle manufacturers, the chemical industry and fuel-cell producers participated heavily in the FCH joint undertaking of the EU, as well as in national projects (e.g. the Clean Energy Partnership (CEP), the National Organisation for Hydrogen and Fuel Cells (NOW) and the National Platform for Electro-Mobility (NEP) in Germany). In parallel, and partly with support through these instruments, the industry developed concept and prototype vehicles (e.g. the Toyota Mirai, Honda FCV (replacing the FCX) and Volkswagen Splinter). Unlike electric cars, which are available now for sale by many manufacturers, fuel cell cars still suffer due to the lack of a hydrogen fuelling infrastructure.

#### 3.4.3 Research activities and outcomes

## 3.4.3.1 Technology status and research achievements

Out of the approximately 120 projects with results available in TRIP related to urban mobility in the late 6<sup>th</sup> and the 7<sup>th</sup> framework programme, 11 studies directly relate to alternative fuel or low carbon vehicles. They can be categorised by propulsion technologies, by the field of application or by the nature of the study. Propulsion technologies mainly branch into electric vehicles, hydrogen and fuel cell vehicles, and efficient combustion technologies (including CNG, liquefied natural gas (LNG), etc.). Fields of application mainly denote transport modes (car, public transport and goods vehicles), but also include infrastructures. Finally, the type of study means the type of activity performed (i.e. implementation and demonstration, feasibility assessment or implementation guidance (campaigning, etc.)).

#### 3.4.3.2 Multiple propulsion systems

Research on low carbon vehicle technologies dates back to the late 1990s. One of the pioneering projects of the European Commission's 4<sup>th</sup> RTD programme was 'Urban Transport: Options for Propulsion Systems and Instruments for Analysis' (UTOPIA, 2000). The project identified a number of barriers to implementing alternatively fuelled vehicles, including lifecycle costs, the availability of appropriate infrastructure, and acceptance by potential users and public administrations. The project carried out demonstration cases for implementation, collected good practice guidance and compiled the necessary information to get decision makers interested in the topic. The final recommendations focused on good implementation practices and on framework conditions (such as binding fuel standards, green procurement by government bodies, green labels and environmental zones). Niche markets like urban buses are considered more appropriate for promoting green fuels than private cars.

In the sixth framework programme, the CIVITAS project 'Mobility Initiatives for Local Integration and Sustainability' (MOBILIS, 2009) picked up the concern for testing and exchanging good practices in implementing advanced mobility solutions. Among many other topics, MOBILIS worked on transition strategies towards alternative fuel production and use, and the costs and benefits of using new technologies in transport. In five partner cities, alternative fuels and clean, energy-efficient vehicles were put into operation, and partners improved their knowledge of the related benefits and constraints. Potentially, the most profound impacts of the demonstration measures are the increased experience and familiarity of decision-makers with new technologies and concepts, and the increase of user participation and awareness.

The FP7 project 'Clean Drive – A campaign for Cleaner Vehicles in Europe' (CLEAN DRIVE, 2013) turned attention towards the sales channels for alternatively fuelled vehicles. By working with 10 groups of car dealers in 9 EU countries, and by developing campaigns and training materials, the project found evidence that participating car dealers will, on average, double the share of the total car sales that emit under 120 g CO<sub>2</sub>/km.

#### 3.4.3.3 Electric vehicle (EV) technologies

Three projects for which results are available directly delved into the development of vehicle technologies and came up with prototypes. The ELVA project explored the new freedom in designing urban cars when going from traditional combustion engines to fully electric propulsion and power trains. Modular design concepts with a high level of intrinsic safety formed the cornerstones of the project. Based on an assessment of technology options that are likely to be available by 2020 and a pan-European customer survey, three vehicle concepts and a detailed design manual for future e-cars were developed. The architecture of the three concept vehicles was not radically different compared to conventional vehicles, but well-established approaches were used where they were seen to be useful.

In a similar way, the project 'Building blocks concepts for efficient and safe multiuse urban electrical vehicles project' (WIDE-MOB, 2014) researched a wide variety of components of electric cars from aerodynamics over lightweight materials, drive train, system optimisation and energy storage components to solar panels for range extension. The prototype vehicle developed by the WIDE-MOB project demonstrated that compliance with most stringent safety requirements can be achieved while meeting most users' demands in terms of driving range and necessity for charging, acceleration and fun to drive. The positive and successful experience of WIDE-MOB, in terms of novel knowledge and patents generated, established the base for a European platform for the development of micro electrical vehicles including standardisation-related aspects to make electrical mobility safer and more efficient.

Concerns about the negative impacts of electromagnetic fields (EMFs) upon drivers and passengers of electric vehicles were investigated by the project EM SAFETY. Starting with relevant impact assessments and measurement techniques, the project aimed to provide a prototypical vehicle architecture eliminating, or at least mitigating, the potentially harmful impacts of EMFs based on the demonstrator developed by the FP7 project 'Integrated Enabling Technologies for Efficient Electrical Personal Mobility' (P-MOB, 2013). The work of EU, US and multinational institutions indicated that low frequencies between 1 and 10 MHz should be most critical for human health. Measurements of 11 cars with electric, hybrid, fuel cell and combustion engines revealed that actual field intensities remained well below the International Commission on Non-Ionising Radiation Protection (ICNIRP) reference levels. However, measurements indicated a safety problem as low frequency EMFs can impact on-board electronic systems.

The ELCAR study considered a different part of the electric vehicle lifecycle, producing e-mobility lifecycle assessment recommendations. As some components of electric cars (e.g. the mining and processing of raw materials for batteries and motor parts) have considerable negative environmental impacts, the study adapted the guidelines from the International Reference Life Cycle Data System (ILCD) handbook to the specificities of electric vehicles. The work programme considered battery

and electric component production; typical vehicle utilisation and driving cycles; interaction between electricity storage, power generation and grid services; and end of life and recycling at different stages of the EV's life. The final guidelines, besides giving technical guidance and discussing input data, emphasise the sensitivity of an appropriate public communication of the scope and limits of life cycle assessment (LCA) results.



#### 3.4.3.4 Hydrogen and fuel cell technologies

Following the recommendations of UTOPIA, the CUTE project pioneered the implementation of fuel cell buses in nine European cities with one of the single largest budgets for a demonstration project granted until then by the European Commission. The project involved the deployment of 27 fuel cell buses plus the production and storage of the necessary hydrogen fuel. Accompanying the two-year, real-life test were certification processes, training and education, and lifecycle cost assessments. Experiences after 800 000 kilometres travelled by the fuel cell buses were reported to be very positive - availability and reliability of the technology and the user satisfaction were high. The longest lifetime for fuel cell stacks achieved in this study was 3 200 operating hours, which exceeded all expectations. However, improvements in fuel consumption through hybridisation and the reliability of some electrical components could be improved. It was identified that steam reformers for smaller filling stations need improvement. Accompanying studies found that the energy efficiency of the whole system was poor. Therefore, the environmental efficiency largely depends on the level of renewable energies used for hydrogen production. The costs were also considered problematic and need to be lowered to make hydrogen buses competitive with conventional diesel buses.

Besides market demonstrations, the HYCHAIN MINI-TRANS project looked at the production scale of light fuel-cell vehicles by developing modular vehicle designs. The project also looked at fuel production options and at business models for marketing light EVs. The project rolled out around 130 vehicles from fuel cell powered wheel chairs to mini buses. Due to the high costs of vehicle and hydrogen production, the project recommended exploiting market niches for smaller vehicles.

Dedicated fleet applications were the focus of the FP6 project 'Lombardia & Rhein-Main towards Zero Emission: Development and Demonstration of Infrastructure Systems for Hydrogen as an Alternative Motor Fuel' (ZERO REGIO, 2010). With fleet tests in the two regions, the project found many technical and organisational issues around hydrogen transport and refuelling, including high pressure pipelines and quick refuelling with, 350 bar supply. Acceptance has been approved and the break-even point for economic viability is considered at a crude oil price of USD 90 to USD 100. The market introduction cell technologies are seen as a medium to long-term endeavour, which still need a number of administrative barriers, such as approval standards and incentives, to be solved.

#### 3.4.3.5 Transferability

The ELVA project provided a detailed design manual for new vehicles, which can be applied irrespective of country borders and by all vehicle manufacturers. In a similar way, the WIDE-MOB project established a platform for the future improvement and new development of electric vehicles.

All of these elements have been driven or supported by leading European car manufacturers. Therefore they can

be considered relevant for the sector as a whole. However, in the case of some projects (e.g. WIDE-MOB) patents have been issued that limit the usability of concrete outputs by competitors within the vehicle industry.

The transferability of demonstration results between cities and regions provides a mixed picture. On the one hand it is limited because the pre-conditions, needs, geographical structures, administrative processes or experiences with new technologies strongly vary. On the other hand, pure technology knowledge and lessons of good implementation practices are applicable to many environments.

An important issue for hydrogen and fuel cell technologies is the development in the stationary fuel cell market. Experience gained in applications such as fork-lifts, emergency power generation or combined heat and power units are expected to advance the technology development for fuel cell electric vehicles. Knowledge advances on hydrogen production and transport in all of these fields are perfectly transferable and should help to overcome remaining technical and economic barriers.

#### 3.4.3.6 Policy implications

The ELVA showed that even the technical concepts of vehicles may have impacts on policy design. Firstly, new vehicle concepts change the way people use vehicles and, thus, call for advanced multimodality concepts. Secondly, the use of innovative and low emission vehicles needs to be rewarded by respective regulations and pricing schemes at an urban level. Generalising across all reviewed research projects on electric and fuel cell vehicles, we can notice that new technologies with characteristics different from low-cost conventionally powered vehicles need protected niche markets helping them to mature and become competitive.

Looking at the several waves of technologies supported by the European Commission in the past two decades – from electric propulsion in the early and mid-1990s over hydrogen and biofuels and back to electromobility – indicates that pushing particular technologies might alienate fuel and vehicle industries. The primary goals of reducing GHG and air emissions, and of reducing dependency on fossil fuel imports might be partly overwritten by technical debates. Incentives for low impact technologies should focus on the potential and the actual benefits of various technology options rather than on technology-related performance indicators, such as the share of electric cars or the share of hydrogen or biofuels in vehicle fuel mixes.

Finally, clean vehicles are only one part of the solution towards a low carbon transport system. Replacing individual motorised travel by public transport or, where possible, by non-motorised alternatives, and shorter and fewer trips need to be considered in a sustainable policy strategy as well. The challenge to be taken up by future research is to form general and goal-driven incentive systems which, despite the high level of complexity, provides clear guidance for transport users, transport suppliers, vehicle manufacturers and fuel producers on which way to go.

#### 3.5 Sustainable public transport

#### 3.5.1 Preliminary recommendations

Research in the sustainable public transport in urban areas sub-theme focuses on the better functioning of the collective transport and its infrastructure. It further analyses how to increase the attractiveness of collective passenger transport for various groups of users and estimates future development trends. It includes topics like ticketing and tariffs, public transport network, safety and security, and fleet management. This research can be divided into four streams.

The first stream looks at solutions for the future, explicitly those that might be adopted relatively soon, including possibilities to improve the intermodality of passenger transport and the larger usage of information technologies. The second stream reflects recent changes in society (such as ageing). It provides recommendations for better adjustment and higher attractiveness of public transport services to specific groups of users (e.g. elderly people) for wider usage of bicycles and walking for short distances and interconnectivity of transport modes, better connectivity of public transport at European border areas, etc. It also contributes to increased awareness and acceptance of new sustainable mobility measures. The third research stream focuses on the use of ITS and the newest technologies in urban public transport modes and services. Research focuses on topics like better and integrated ticketing, and providing real-time information for drivers, transport operators and passengers. The fourth stream tests and develops possible alternative fuels and propulsion systems, like hydrogen and fuel-cell buses, biofuels and approaches to energy savings.

The European policy puts still more attention on urban areas and their challenges including sustaining public transport. This topic is discussed in several EU documents. The most relevant is the Transport White Paper. It sets goals and initiatives up to 2050, including those tackling directly or indirectly urban collective transport. One goal is to halve the use of 'conventionally fuelled' cars in urban transport by 2030 and phasing them out of cities by 2050. To fulfil this goal, research should focus on how to increase the attractiveness of public transport, how to organise it better, how to build interchange zones/nodes, possible effective measures of mobility management, development of  $CO_2$ -free alternatives for urban motor traffic, and building the potential of new and unconventional transport systems and vehicles.

Goal 8 of the Transport White Paper specifies that the framework for a European multimodal transport information, management and payment system shall be established by 2020. This goal might be supported by research findings on the applications of information technologies and the development of payment systems. Research should also reflect the Transport White Paper initiative 'to create the framework conditions to promote the development and use of intelligent systems for interoperable and multimodal scheduling, information, online reservation systems and smart ticketing. This could include a legislative proposal to ensure access of private service providers to travel and real-time traffic information'. The Transport White Paper also calls for prioritising the most promising technologies and bringing together all involved actors.

The projects analysed in this sub-theme are generally in compliance with this demand. However, there are research gaps in some topics. In the surveyed projects, deeper analysis of public transport infrastructures is missing, especially drawing routes of its further development using innovative and unconventional approaches. Similarly, there is no research project on 'individualisation' and specialisation of collective transport (i.e. services like bus on demand and shared taxis). Economic analysis represents another under-researched area among the analysed projects. For example there is limited research on urban transport taxation, fare policies, etc.; and analysis on financing, social assessment; and evaluation of various public transport services and measures.

The 'Co-operative Networks for Intelligent Road Safety' project (CONPASS, 2002) showed that there is only limited focus on international short distance-transport. In public discussions, cross-border public transport is often thought of as longdistance services by rail, although the majority of cross-border travellers make local and regional trips. The EU is supporting the concept of trans-European networks (TENs). However, similar actions on local and regional levels are missing. To contribute to the further sustainability of cross-border trips, a cross-border public transport master plan is a necessary planning tool.

Some projects (e.g. CUTE) revealed that there is specific technical research needed regarding vehicles and propulsions. For example, the overall efficiency of the hydrogen production and distribution system needs to be greatly improved. The durability and power density of fuel cells has to be further enhanced, while the hydrogen storage systems need to be simplified and made less expensive. Drive trains of future fuel cell buses need to be improved, especially with regard to electrical components such as electric motors, high voltage battery systems and their associated control strategies.

The project 'Sustainable, workable intermodal transport choices' (SWITCH, 2000) identified the multiple topics for further research – research on acceptability of introducing European standards for interchanges, covering access, intermodal signage and cycle provision.



#### 3.5.2 Research environment and development

Under this sub-theme, 13 research projects were analysed – 12 were financed by various European programmes and one by a national programme. Table 3-5 summarises projects included in this analysis, their duration and source of funding.

The sub-theme includes a range of topics and approaches. The oldest analysed projects were aimed at new concepts of transport, intermodality and alternatives to cars for short trips. These projects analysed the potential of new transport services like elevated passenger transport, underground freight transport and airships. They also discussed financial and commercial hurdles, and regulatory barriers to these alternatives ('Reducing Congestion by Introducing New Concepts of Transport', (RECONNECT)). Project SWITCH demonstrated good practice in the provision of intermodal passenger transport systems (including improved information to travellers, improved interchanges and integrated ticketing) and in assessing the impacts on transport operation, traveller behaviour, the environment and economic performance. Multimodal passenger transport became a focus of projects starting in 2000. The project 'Intelligent In-Vehicle Terminal For Multimodal Flexible Collective Transport Services' (INVETE, 2002) analysed user needs for regular and flexible collective transport at in-vehicle terminals. Based on these findings, a terminal using separate modules at hardware and software levels was constructed and tested during a small-scale verification and a large-scale demonstration. The CONPASS project aimed at the better connection of public transport in European border areas. Its methodology was based on a questionnaire survey, case study analyses and demonstrations. The project 'Bus Priority Strategies and Impact Scenarios Developed on a Large Urban Area' (PRISCILLA, 2002) focused on bus priority using evaluations of the existing measures and further testing of the selected measures with the best results. Hydrogen and fuel-cell buses were tested during the CUTE project. The CIVITAS project TELLUS started in 2002 and its focus was on the integration of planning and implemented measures to support sustainable mobility.

Project acronym	Project name	Project duration	Source of funding
UG207	Potential for mode transfer of short trips	04/1998-06/2001	DfT Regional and Local Transport
RECONNECT	Reducing Congestion by Introducing New Concepts of Transport	12/1998-03/2000	FP4 – TRANSPORT RTD
SWITCH	Sustainable, workable intermodal transport choices	01/1999-12/2000	FP4 TRANSPORT RTD
CONPASS	Better CONnections in European PASSenger Transport	01/2000-06/2002	FP5 – GROWTH – KA2 – Sustainable Mobility and Intermodality
INVETE	Intelligent In Vehicle Terminal For Multimodal Flexible Collective Transport Services	01/2000-05/2002	FP5 – IST – KA1 – Systems and services for the citizens
TRENDSETTER	Setting Trends for a Sustainable Urban Mobility	06/2000-12/2002	FP5 – EESD KA6 – Economic and Efficient Energy for a Competitive Europe
PRISCILLA	Bus Priority Strategies and Impact Scenarios Developed on a Large Urban Area	11/2000-09/2002	FP5 – IST – KA1 – Systems and services for the citizens
CUTE	Clean Urban Transport for Europe	11/2001-06/2006	FP5 – EESD KA6 – Economic and Efficient Energy for a Competitive Europe
TELLUS (Overview)	Transport & Environment Alliance for Urban Sustainability	02/2002-01/2006	FP5 – GROWTH – KA2 – Sustainable Mobility and Intermodality
AENEAS	Attaining Energy Efficient Mobility in an Ageing Society	08/2008-05/2011	IEE
EBSF	European Bus System of the Future	09/2008-08/2012	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
INTERCONNECT	Interconnection between Short and Long Distance Transport Networks	06/2009-05/2011	FP7-TPT – Transport (Including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)
MOBILE2020	More biking in small and medium sized towns of Central and Eastern Europe by 2020	04/2011-01/2014	IEE

#### Table 3-5 Projects identified under the sustainable public transport sub-theme

The projects starting after 2010 focused on:

- biking in small and medium sized towns of Central and Eastern European countries (promotion of these transport modes and education of relevant stakeholders);
- interconnections between short and long-distance transport networks ('Interconnection between Short and Long-Distance Transport Networks' (INTERCONNECT, 2011));
- European bus systems of the future (improved vehicles and intelligent systems making efficient use of information and providing different bus system solutions adapted to specific needs of all stakeholders) ('European Bus System of the Future' (EBSF, 2008-2012));
- energy efficient mobility in an ageing society ('Attaining Energy Efficient Mobility in an Ageing Society' (AENEAS, 2011)).

The analysed projects contribute to the key challenge on how to reconcile the increased demand for transport with the need to reduce its impacts on the physical, social and human environment. Therefore it is clear that they further develop and implement the objectives of the Transport White Paper and those of national policies promoting transport sustainability from economic, social and environmental points of view, and enhancing the efficiency and quality of transport systems and services. The projects also contribute to the EU policy of sustainable mobility by enhancing the attractiveness and accessibility of more sustainable public transport, and by enhancing efficiency and quality of public services through the improvement of the overall cost-effectiveness of transport operations and of the related telematics infrastructure.

At the European level, the research more or less reflects the policy targets. However, a bigger emphasis could be placed on the analysis of transport behaviour and the factors influencing it, including economic ones. Demonstrating and testing the available technology are very important steps for supporting sustainability. The availability of information on travelling time and routing alternatives is equally relevant.

The topic of sustainable public transport is very wide, giving rise to overlaps and synergies between projects, and providing a range of possibilities to cooperate within the European research community. A typical example of such cooperation is the CIVITAS initiative. CIVITAS projects have a strong focus on sustainable mobility, including public transport, and have placed an emphasis on demonstration, transfer and exchange of experience.

The analysed projects offered testing and demonstration of new technologies in public transport in different conditions, especially regarding interconnectivity, new kinds of vehicles, fuels and propulsion systems. There is a potential for the exchange of experience with alternatively provided collective transport and vehicles, but also of discussions and modelling future visions and development of the sustainable urban mobility sector. It is a possibility to exchange experience in providing improved services with respect to specific groups of passengers such as the elderly, children, disabled, women, etc.

In the context of the use of services by the elderly, the results of the AENEAS project showed that elderly people are not a homogeneous target group and, as such, there is no 'one size fits all' approach. For example, a 65-year old person might consider it ridiculous to receive training where everything is repeated twice. For a fragile, very old person on the other hand, it can be essential that venue, contents and communication are accessible by all means. In other words, when reading these recommendations, it is important to have the specific target group in mind and consider what might be appropriate and what may not.

Overlaps can be found also among research projects on acceptance and awareness. The analysed projects bring a large potential for dissemination of best practice, worst practice and lessons learned to other cities, and the community of researchers and practitioners.

#### 3.5.3 Research activities and outcomes

The CUTE project showed that fuel cell buses and some aspects of the hydrogen infrastructure gave surprisingly high levels of availability. The project also demonstrated that the vision of a future transport system based on fuel cells and hydrogen can become a reality when all of the optimisation potentials identified in CUTE are realised and transferred into series production.

More than 4 million passengers were transported by, and directly experienced, fuel cells. The distance driven and the number of operating hours of the bus fleet are perhaps the most impressive figures from this project. They document the huge step forward with regard to the lifetime and durability of the fuel cell system. Never before had a hydrogen technology project demonstrated such an outstanding operating success. Buses driven by regular bus drivers in regular traffic under normal operating conditions completed a distance of more than 20 times around the globe, producing a wealth of data and building a vast pool of experience. However, the energy efficiency of the hydrogen production and dispensing infrastructure was generally poor. This means that the overall environmental impact of the fuel cell bus system (vehicle and fuel supply) was highly dependent on its own efficiency and on the hydrogen supply route chosen, particularly the source of energy input. This demonstrates yet again the importance of increasing the level of renewable inputs to stationary energy production.

The SWITCH project proved that interchange design should take into account identified user needs. It recommends that:

- intermodality needs should be planned and managed from a network rather than a site-specific perspective, with cooperation between organisations;
- pre-trip and real-time information should be provided and signage should be standardised;
- access issues must be foremost when designing interchanges, with high-quality park-and-ride car parks, kiss-and-ride spaces and full integration of taxi services with public transport.

The estimated impacts of the measures at the test sites were relatively small, typically between 1 % and 2 % in terms of reductions in energy use and emissions. Limited increases in the patronage of public transport were also identified. However, the effects of the packages of measures as a whole were not measured and longer-term impacts could not be gauged – these are expected to show greater benefits.



Under the project 'Setting Trends for a Sustainable Urban Mobility' (Trendsetter, 2000-2005), all of the cities involved have made significant efforts to improve the public transport system to attract more passengers. Some of the measures have been aimed at improving the access to public transport and others to facilitate trip planning for the smartest choice.

The city of Lille has improved the safety and security of its public transport system, using technical equipment and additional personnel. It has also implemented integrated fares in the region. Stockholm and Lille have prepared for the implementation of smart card systems. The improved safety and security, the fare integration system, park-andride facilities, creation and improvements of multimodal nodes, and the implementation of service bus lanes supported an increased use of different forms of public transport in Lille.

In Graz, 60 bus and tram stops, situated at important junctions, were rebuilt and improved to make them more customer friendly. Stockholm and Graz have increased the quality of services in the public transport system by using regular quality surveys displaying real-time information at bus stops and on the Internet, introducing a travel guarantee for delays, using mystery shoppers to report on quality and introducing incentives for contractors to perform better.

To make the buses more efficient, dynamic bus priority systems have been implemented in Prague and Stockholm, while Lille has introduced a bus lane with high-level service, the first in a series of 12 similar bus lanes. New bus lanes for special needs have been implemented – one to a hospital area in Prague, and one between Graz and its suburbs on weekend nights.

The attractiveness and image of public transport has also been improved by the introduction of biogas buses in Stockholm and Lille, and biodiesel buses in Graz. More than 230 buses, fuelled with biodiesel or biogas have been demonstrated in the three cities. Trendsetter cities – those participating in the Trendsetter programme – further introduced real-time information systems with information on arrivals and departures, trip-planning tools on the web and mobility centres.

The national research project 'Potential for mode transfer of short trips' (1998-2001) was based on sociological surveys in several English cities. Alternatives to the car were identified for nearly 80 % of short car trips – with business and work trips the least likely to transfer and taking children to school the most likely. Of all the short trips made by people in cars, about 31 % could transfer to walking, 31 % could go by bus and 7 % could cycle. The single policy intervention that would do most to attract people out of their cars is to improve bus services, which could attract up to 21 % of car drivers, particularly by increasing route coverage and frequency. There is little in the nature of specific policy intervention that could encourage more walking or cycling, so it would require personal initiative. Hence, there is a need to make car drivers more aware of the benefits of walking and cycling.

Most of the projects had a testing and piloting phase, which led to practical use. However, some steps to get research to practical use are needed at all levels (local, national and European). Cities need to inform potential stakeholders about the possibilities of various public transport improvements and their effects, coordinate the consolidation schemes, and help contractors with administrative and legal issues. Political support at all levels is also important, since funding is needed in the beginning. Enthusiastic politicians can often make things happen, especially when innovative measures might be implemented.

Communicating with the public (potential collective transport users) is also needed when targeting public transport. Passengers usually strive for journeys with few (and smooth) interchanges. Measures targeted at developing this are vital to make public transport more attractive (e.g. easy and integrated ticketing with smart-card systems, park-and-ride facilities, secure parking places for bicycles, real-time information systems at stations and web-based trip planning tools).

According to the RECONNECT project, better administration is needed also for:

- vehicle automation and guidance systems, communications and control systems;
- development of standards (e.g. for the safety requirements for new vehicle concepts);
- in-depth assessment of the environmental, noise and safety impacts of new concepts;
- the development of technologies for underground infrastructure (ground exploration, tunnel driving, tunnel lining and standardisation of dimensions).

The TRANSPOWER project stated that under-researched and under-developed fields in public transport are fare integration, integration with other modes and integration with urban logistics. An institutional reform of urban public transport needs to be tackled more broadly as well.

#### 3.6 Sustainable Urban Mobility Plans

#### 3.6.1 Preliminary recommendations

There is no simple or common definition of Sustainable Urban Mobility Plans (SUMPs) for all European countries. That is why SUMPs vary from country to country and why some countries have not yet defined their SUMPs. The tradition of planning also differs substantially across countries. The ENDURANCE project observed that many countries use documents similar to SUMPs (or with some SUMP elements), but not all of the elements were covered.

Several definitions of SUMPs exist. The most often used SUMP definition was formulated in the guidelines 'Developing and implementing a Sustainable Urban Mobility Plan' (Rupprecht Consult, 2013) which was elaborated under the project ELTIS Plus. It specifies that the purpose of a SUMP is to create a sustainable urban transport system by addressing at least the following objectives:

- ensure the transport system is accessible to all;
- · improve safety and security;
- reduce air and noise pollution, GHG emissions and energy consumption;
- improve the efficiency and cost-effectiveness of the transport of persons and goods;
- contribute to enhancing the attractiveness and quality of the urban environment and urban design.

The policies and measures defined in a SUMP cover all modes and forms of transport in the entire urban agglomeration, including public and private, passenger and freight, motorised and non-motorised, moving and parking.

Characteristics of SUMPs are:

- a participatory approach;
- a pledge of sustainability;
- an integrated approach;
- a focus on achieving measurable targets derived from short-term objectives, aligned with a vision for transport and embedded in an overall sustainable development strategy;
- a review of transport costs and benefits, taking into account the wider societal costs and benefits, also across policy sectors;
- a method comprising the following tasks:
  - status analysis and baseline scenario;
  - definition of a vision, objectives and targets;
  - selection of policies and measures;
  - assignment of responsibilities and resources;
  - arrangements for monitoring and evaluation.

The analysed projects from this sub-theme can be divided into the following streams according to their topics:

- improvement in the quality of SUMPs, focusing on the most complicated parts of these plans (monitoring and evaluation, citizen involvement, Identification of the most effective policy measures, etc.), their promotion and support of the national authorities (eight projects);
- mobility management and mobility plans, packaging of measures of sustainable mobility, database of good examples, training and raising awareness (nine projects);
- analysis of transport behaviour (two projects);
- CIVITAS projects (implementation of a range of sustainable mobility measures in cities) (four projects);
- analysis of a specific transport problem automated transport systems, road-user charging, etc. (nine projects).

An analysis of topics covered in these research projects indicates that there is a deeper research missing on defining the minimum standards for SUMPs and their harmonisation within the EU Member States. Even if some supporting initiatives such as ENDURANCE have taken place, the focus is on

- updating the state of the art;
- building national SUMP networks and activating European cities to start SUMPs;
- the dissemination of the idea of SUMPs among EU Member states and raising awareness among European cities, transport planners and experts more so than research activities such as fostering further comparisons and inspiration among countries;
- the common evaluation of SUMP practices across EU.

The existing funding possibilities of SUMPs include European Structural and Investment Funds, Horizon 2020, Connecting Europe Facility - to name the most important ones. As part of CIVITAS 2020, local partnerships implementing and testing new urban mobility approaches under real-life conditions can be supported. Similarly, the funding programme 'Connecting Cities, Building Success' (URBACT III, 2014 – 2020) acts as a European exchange and learning programme promoting sustainable urban development. It will enable European cities to work together to develop solutions to urban challenges and share good practices, lessons learnt and solutions found with all stakeholders involved in urban policy throughout Europe. Based on the analysis of the relevant research projects, it appears that the funding priorities should focus more on how to create an 'ideal' SUMP, how to analyse impacts of SUMPs and of their particular tools and packages of measures, the further use of ITS and intelligent personalised data, on new effective tools for supporting sustainable mobility and analysis of transport behaviour, mode choice awareness raising and stakeholder involvement. An increase in knowledge about SUMPs among practitioners, politicians and university students could also contribute to a better understanding of this kind of plan, its implementation and the evident impacts.

#### 3.6.2 Research environment and development

Under this sub-theme, 32 research projects were analysed – 28 of them were financed by various European programmes and four of them by a national programme.

Table 3-6 summarises projects included in this analysis, their duration, source of funding and their relevance to the SUMP topic.

#### Table 3-6 Projects identified under the sustainable urban mobility plan sub-theme

Project acronym	Project name	Project duration	Source of funding	Main aim/relevance to SUMP
	Public Transport Interchange Preliminary Designs	01/2004-01/2006	Ireland: PFC – Platform for Change Transportation Strategy	Plans of interchanges at 2 rail stations and DART station; citizens involvement; future scenarios modelling
SVI 2001/504	A marketing approach for the promotion of pedestrian and bicycle traffic in Switzerland	06/2004-07/2006	Switzerland: SVI – Swiss Association of Transportation Engineers (various projects)	Marketing of slow transport modes
NICHES	New and Innovative Concepts for Helping European Transport Sustainability	11/2004-03/2007	FP6-SUSTDEV-2 - Sustainable Surface Transport	Stimulation of a wide debate on innovative urban transport between relevant stakeholders
MOBILIS	Mobility Initiatives for Local Integration and Sustainability	01/2005-01/2009	FP6-SUSTDEV-2 – Sustainable Surface Transport	CIVITAS project; main aim to develop and implement broad integrated packages of policies and measures
CARAVEL	Travelling Towards a New Mobility	02/2005-02/2009	FP6-SUSTDEV-2 – Sustainable Surface Transport	CIVITAS project; main focus – to embed the individual measures into overarching urban policies covering strategic objectives
SMILE	Sustainable Urban Transport for the Europe of Tomorrow	02/2005-01/2009	FP6-SUSTDEV-2 – Sustainable Surface Transport	CIVITAS project; focus on air quality
NRP 54 – A7	Moving towards sustainability? The consequences of residential relocation for mobility and the built environment	10/2005-04/2008	Switzerland: NRP 54 – Sustainable Development of the Built Environment (National Research Programme 54)	Research on transport behaviour
SPICYCLES	Sustainable Planning & Innovation for biCYCLES	01/2006-12/2008	IEE	Planning of cycling, awareness raising
CURACAO	Coordination of Urban Road- User Charging Organisational Issues	04/2006-03/2009	FP6-SUSTDEV-2 – Sustainable Surface Transport	Research on road-user charging
TRANSPOWER	Supervised Implementation of Sustainable Urban Transport Concepts	08/2006-08/2009	FP6-SUSTDEV-3 – Global Change and Ecosystems	Building technology and manpower capacity, supporting decision- making; implementation of innovative measures
ADICCT	Assessing and Developing Initiatives of Companies to control and reduce Commuter Traffic	01/2007-07/2011	Belgium: SSD – Science for a Sustainable Development	Mobility management of companies
BMW	Weekly patterns in behaviour and mobility	01/2007-01/2009	IEE; Belgium level	Analysis of weekly mobility patterns
MOBIDAYS	Sustainable Mobility Days	01/2007-06/2008	FP6-SUSTDEV – Sustainable Development, Global Change and Ecosystems – Priority Thematic Area 6 (PTA6)	Analysis of barriers and drivers of sustainable mobility including technical and socioeconomic ones
COMMERCE	Creating Optimal Mobility Measures to Enable Reduced Commuter Emissions	10/2007-10/2010	IEE	Improve quality of mobility plans for small and medium sized companies

Project acronym	Project name	Project duration	Source of funding	Main aim/relevance to SUMP
CONCERTOUR	Concerted Innovative Approaches, Strategies, Solutions and Services Improving Mobility	01/2008-09/2009	FP7-TPT – Transport (including Aeronautics)	Involve decision makers, provide best practices, improving understanding and establishment of long term activities
NICHES+	New and Innovative Concepts for helping European Transport Sustainability – Towards Implementation	05/2008-04/2011	7 <sup>th</sup> RTD Framework Programme	Exploration of innovative urban transport concepts, which are high on the European and local agenda, while also looking into the needs of its potential users and implementers
AENEAS	Attaining Energy Efficient Mobility in an Ageing Society	08/2008-05/2011	IEE	Raising awareness; training older people
WISETRIP	Wide Scale Network of E-systems for Multimodal Journey Planning and Delivery of Trip Intelligent Personalised Data	08/2008-11/2010	FP7-TPT – Transport (including Aeronautics)	Main objective – to develop and validate mobility service platform providing and personalising multimodal travel info sources
CITYNETMOBIL	City Network for Fair Mobility	09/2008-11/2011	FP7-TPT – Transport (including Aeronautics) – Horizontal activities for implementation of the transport programme (TPT)	City studies on automated transport system (ATS) for four cities; raise awareness on ATS
CIVITAS MIMOSA	CIVITAS Making Innovation for Mobility Sustainable Actions	10/2008-10/2012	FP7-TPT – Transport (Including Aeronautics)	CIVITAS project; MIMOSA cities adopted an innovative integrated approach involving technology, citizen engagement and partnership to improve infrastructure
DELTA	Concerted coordination for the promotion of efficient multimodal interfaces	01/2009-12/2010	FP7-SST – Sustainable Surface Transport	Intelligent mobility tools and practices guidelines reflecting seasonal demand; web-based decision support instrument
ELTIS-plus	Promoting Sustainable Urban Mobility Plans	01/2011-01/2012	IEE	Europe's main observatory on urban mobility
QUEST	Quality management tool for Urban Energy efficient Sustainable Transport	05/2011-11/2013	IEE	A quality management tool developed to help cities to set up and further develop their sustainable mobility policies and to support processes in the city
ADVANCE	Auditing and Certification Scheme to Increase the Quality of Sustainable Urban Mobility Plans in Cities	06/2011-06/2014	IEE	Improvement of the quality of SUMPs; promotion of SUMPs throughout Europe
POLY-SUMP	Polycentric Sustainable Urban Mobility Plans	04/2012-10/2014	IEE	A methodology for poly-centric regions; testing of concrete planning processes towards the adoption of mobility plans
PUMAS	Planning Sustainable regional- Urban Mobility in the Alpine Space	07/2012-06/2015	Alpine Space Programme, ERDF and the Partner States	Advance SUMP; develop, implement and evaluate 7 pilots; create the Alpine Space community and the National and Alpine Reference Point for SUMP in Slovenia
TIDE	Transport Innovation Deployment for Europe	10/2012-09/2015	7 <sup>th</sup> RTD Framework Programme	Enhancement of the broad transfer and take-up of 15 innovative urban transport concepts; establishing them as mainstream measures. Sustainable Urban Mobility Plans were a horizontal topic to integrate the cluster activities

#### Table 3-6 (continued) Projects identified under the sustainable urban mobility plan sub-theme

Project acronym	Project name	Project duration	Source of funding	Main aim/relevance to SUMP
CH4LLENGE	Addressing the four Key Challenges of Sustainable Urban Mobility Planning	03/2013-03/2016	IEE	Stakeholder participation and citizen involvement; Institutional cooperation between sectors and disciplines; Identification of the most effective policy measures; Monitoring and evaluation of progress in SUMP development
BUMP	Boosting Urban Mobility Plans	05/2013-05/2016	IEE	Support to local authorities in the development of Sustainable Urban Mobility Plans
ENDURANCE	EU-wide establishment of enduring national and European support networks for sustainable urban mobility	05/2013-05/2016	IEE	Building of 25 national networks on SUMPs; trainings and policy exchange for transport experts and cities on SUMP
EVIDENCE	Evidence of the Proven Economic Benefits of Sustainable Transport Initiatives to Facilitate Effective Integration in Urban Mobility Plans	03/2014-02/2017	IEE	Compelling evidence to demonstrate the economic benefits of delivering transport investment through a SUMP framework; show the economic value of successful sustainable transport schemes

#### Table 3-6 (continued) Projects identified under the sustainable urban mobility plan sub-theme

Of these 32 projects, only eight were focused solely and comprehensively on SUMPs:

- 'Auditing and Certification Scheme to Increase the Quality of Sustainable Urban Mobility Plans in Cities' (ADVANCE, 2014);
- · 'Boosting Urban Mobility Plans' (BUMP, 2013);
- 'Addressing Key Challenges of Sustainable Urban Mobility Planning' (CH4LLENGE, 2013);
- 'Support and Dissemination of Information, Knowledge and Experiences in the Field of Sustainable Urban Mobility' (Eltisplus, 2013);
- 'Evidence of the Proven Economic Benefits of Sustainable Transport Initiatives to Facilitate Effective Integration in Urban Mobility Plans' (EVIDENCE, 2014);
- ENDURANCE;
- 'Polycentric Sustainable Urban Mobility Plans' (POLY-SUMP, 2014);
- 'Urban Platform for Advanced and Sustainable Mobility' (PUMAS).

Most of these projects are still running or recently completed.

The other analysed projects include at least some aspects of SUMPs, including approaches to the plan. However, there is no evident topic continuity in research projects among these projects from this sub-cluster over time. Various similar topics were the subjects of projects during the period since 2004. The oldest analysed projects under this sub-theme are national projects focused on the preparation of plans of rail interchange improvements (station building capacity enhancements, signage, ticketing and passenger information improvements, provision of park-and-ride, provision of bus facilities, provision of car and taxi turnabout facility, and designated areas for passenger pick up

and drop off and cycle and pedestrian access), analysis of the consequences of residential relocation for mobility and the built environment, and how to promote pedestrian and bicycle traffic. Between 2005 and 2009, three CIVITAS projects also took place.

Projects that started in 2006 were focused on the analysis of specific measures and policies to enhance sustainable urban mobility including road-user charging and support of cycling. A project analysing behavioural patterns on a weekly basis, and two projects analysing and developing commuting and mobility plans of companies belong to this time period as well.

The newest projects include increasing awareness and participation in the field of mobility and tourism, multimodal journey planning, energy efficient mobility in an ageing society, automated transport systems in sustainable mobility, and multimodal interfaces.

During the most recent time period analysed, the European guidelines on SUMPs were prepared. Furthermore a methodology specifically for polycentric regions was formulated, and an audit and certification process was developed. ENDURANCE focuses on establishing 25 national networks supporting the implementation of SUMPs and disseminating knowledge and best practice on SUMPs.

There are some recommendations on particular research topics that need further actions. The project 'Concerted coordination for the promotion of efficient multimodal interfaces' (DELTA, 2010) focused on efficient multimodal interfaces in tourist regions and identified the following issues as the further main research needs:

- the understanding of seasonal traffic peaks in the concerned regions, especially tourist destinations;
- further analysis of existing mobility schemes and identifying new ones in these areas;

- tools for seasonal mobility management;
- investigating the possibility of exploiting new social networks acting as tools providing real-time information successfully to the relevant target groups;
- promoting research on ITS applications, standardisation and normalisation.

The project 'New and Innovative Concepts for Helping European Transport Sustainability' (NICHES, 2007) suggested the following recommendations for further research:

 The European Commission should provide financial support and guidance for local governments to study behavioural issues. They are very important in seeking to develop a walking and cycling travel culture and to influence private car users to change to soft ('sustainable') modes.

- It is very important to integrate cycling, walking and other soft modes into urban transport, and to integrate urban transport mobility into city planning and city policy.
- Relationships and interdependencies should be examined between ticketing, infrastructure, passenger information, safety and security, and public transport use.



The 'Coordination of Urban Road-User Charging Organisational Issues' project (CURACAO, 2009) which analysed road-user charging, described a number of topics for further research to increase knowledge and understanding of road-user charging according to high, medium and low priority. These are:

#### 1. High priority

- the interaction between acceptability and effectiveness;
- the extent to which results in one city can be transferred to another;
- the implications of design and technology for enforcement;
- the application of new developments in technology and in business systems;
- ways of reducing the costs of technology and business system applications;
- the impacts on the urban economy and, in particular, the differential effects by economic sector and size of firm;
- the effects of road-user charging on different impact groups;
- the interaction between acceptability, equity and, in particular, the impact of scheme design on perceived inequities;
- the requirements for sustaining and adapting road-user charging schemes once implemented;
- comparisons between predicted and actual impacts.

#### 2. Medium priority

- approaches to the design of overall strategies which include road-user charging;
- methods for the design of road-user charging schemes;
- prediction methods;
- understanding of behaviour and, particularly, second-order responses and the behaviour of users of other modes;
- the impacts of road-user charging on liveability and health;
- the dynamics of acceptability over time and the particular role of referenda in testing and promoting acceptability;
- the specification of appropriate timescales and sequences for the implementing urban roaduser charging schemes.

#### 3. Low priority

- the measurement of congestion and travel time reliability;
- development of best practices for evaluating road-user charging schemes;
- methods of appraising secondorder effects.

In addition, some processes of SUMPs need improvement through further research. In particular, analyses of the effectiveness of appropriate measures and of their design to change transport behaviour towards sustainability, the role of particular stakeholders in the planning and implementation of SUMPs, and how to involve stakeholders.

SUMPs are believed to be the key instrument to achieve sustainable mobility in urban areas. That is why the European Commission pays increasing attention to them. The first comprehensive support package in the field of urban mobility was adopted in 2009 (European Commission, 2009). SUMPs are emphasised especially in the Transport White Paper and in the Urban Mobility Package. The latter document gives further help for cities to develop SUMPs (e.g. it formulates recommendations for coordinated actions in specific areas – urban logistics, urban access regulations, ITS deployment in urban areas and urban road safety).

Some topics that tackle SUMPs and promote the uptake of the innovative concept are included among the Horizon 2020 topics. They are:

- enhancing the capacities of local authorities and other stakeholders to successfully plan and implement innovative sustainable mobility measures, technologies and tools on the basis of reliable data and analysis;
- setting up business models and schemes for innovative procurement;
- the development of bankable projects and partnerships.

The document 'A renewed European Union Tourism Policy: Towards a stronger partnership for European Tourism' (European Commission, 2006) introduces the strategy to be pursued for better exploitation of growth and employment potentials of the tourism sector in a sustainable way. It also refers to how the stakeholders can be involved in European Commission actions. That is why the 'Concerted Innovative Approaches, Strategies, Solutions and Services Improving Mobility and European Tourism' project (CONCERTOUR, 2009) concentrated on the creation of synergies between the transport, research and tourism sectors in Europe. Its overall objective was to propose new guiding concepts for tourists based on the successive stages of 'the whole travel itinerary' and to support EU policies in improving the competitiveness of its tourism sector.

The analysed projects from this sub-theme contribute to the key challenge about how to reconcile the increased demand for transport with the need to reduce its impact on the physical, social and human environment. The European-wide policy documents set a clear action to develop and implement SUMPs in larger urban areas. Because the analysed projects contributed to the development of some aspects of SUMPs, they are in line with this EU policy. However, more attention should be paid to the SUMPs as comprehensive documents. There is a need to agree on a set of minimum requirements for a SUMP and translate it successfully to the national legislation/ administration, to prepare a list of appropriate measures and

packages of measures with clear analysis of their various impacts; and contribute to more precise and, at the same time, less burdensome evaluation and monitoring of the implementation of SUMPs, among others. There is also a large potential to focus on smaller cities (fewer than 150 thousand inhabitants) and offer them SUMP guidelines, minimum requirements for SUMPs in small cities and/or agglomeration of small cities. Another important topic is how to check the quality of SUMPs and who would be the responsible authority.

Several synergies can be identified among the analysed projects. In particular, there are strong synergies between the CIVITAS projects and research projects on specific issues like transport behaviour analyses. A substantial number of CIVITAS projects also include SUMPs as their demonstration measures. The CIVITAS projects can benefit from the findings of other research projects. Equally, the research community can build on the experience and findings of case studies of measures applied in the CIVITAS demonstration cities.

#### 3.6.3 Research activities and outcomes

The analysed projects from this sub-theme provided practical deliverables, such as a version of the WISETRIP multimodal travel service platform (available online at www.wisetrip-eu.org) which was developed under the WISETRIP project, and technological and theoretical outputs. The CURACAO project developed technologies such as automatic number plate recognition (ANPR) or DSRC and global navigation satellite systems (GNSS). The development of GPS enables the use of a wider range of pricing systems, including distancebased charging. The 'Assessing and Developing Initiatives of Companies to control and reduce Commuter Traffic' project (ADICCT, 2011) showed that companies can influence the modal choice of their workers. The Swiss national research project revealed that the usual singular measures do not lead to a significant change in mobility behaviour. A possible approach to increase pedestrian and bicycle traffic is to combine coherent singular measures to create packages. In doing so, one would expect synergy effects and ranges of products which are (more) suitable for the target groups. The adaptation of the classic marketing approach is a promising methodological approach to create these packages.



Most of the projects considered under this sub-theme researched some partial topics that are covered by SUMPs or integrated several policy packages in one city and used some of the characteristics of SUMPs such as the participatory approach, integrated approach or a pledge of sustainability. The projects with probably the most comprehensive approach and most corresponding to several SUMP characteristics are 'Supervised Implementation of Sustainable Urban Transport Concepts' (TRANSPOWER, 2009) and CONCERTOUR.

The key aim of the TRANSPOWER project was to supervise the implementation of existing concepts in the field of urban transport by using innovative approaches. The project had to:

- · create a network of cities, businesses and science;
- provide decision-makers in cities and municipalities with information on recent urban transport problems and enable them to guarantee a fast and efficient implementation of new or existing sustainable urban transport concepts;
- support an exchange of know-how between transport SMEs, research centres and policy makers;
- build capacity in terms of technology and manpower by exchanging experiences, presenting best practices and disseminating the results to other regions.

CONCERTOUR was a Horizontal Activity project providing continuous interaction and supporting projects activities to:

- involve key decision-makers at all levels (institutions, associations, public bodies, research institutes, tourism industry, citizens, local businesses, etc.) from EU27 and non-EU countries;
- ensure continuity of proposed actions;
- communicate and publish proposed supporting actions clearly, regularly and widely at every project stage;
- provide the widest possible access to best practices;
- generate a sense of partnership through improved understanding and the establishment of long-term activities.

The adaptation of the marketing approach for pedestrian traffic and cycling proves to be a suitable instrument to increase the effectiveness of promotion measures through the creation of packages. The strong points are:

- focus on promising fields of action;
- quantitative and qualitative goals that are easy to evaluate;
- the explicit consideration of new target groups;
- the plausibility of the generated packages;
- the suitability of the marketing mix (groups of the marketoriented measures) as a controlling instrument.

The generated models of packages are too general to be made a standard practice. It is shown that the formation of packages of measures only makes sense at the interface of local opportunities and synergies. Thus the method needs to be appropriately extended.

The results from the Swiss national project 'Moving towards sustainability? The consequences of residential relocation for mobility and the built environment' (NRP 54 – A7, 2005-2008) show a move to central locations, which is, from the perspective of mobility, a move towards sustainability. Furthermore, the total time spent in traffic in motorised transport went down by more than 40 %, while more time was spent for non-motorised transport. It also realised that the potential of a sustainable mobility measure should not be overestimated. Behavioural changes due to the intervention are about 10 %; these behavioural changes moved mainly towards non-motorised traffic.

The projects specifically focused on SUMPs were ADVANCE, BUMP, CH4LLENGE, Eltis-plus, EVIDENCE, ENDURANCE, POLY-SUMP and PUMAS. They all were (or are) focused on further improvement of SUMPs in specific conditions or of specific aspects of this complex planning approach, and on further promotion of these plans and training of local practitioners from cities.

For example, the ADVANCE project developed and tested a prototype of the audit scheme with the aim of evaluating and improving sustainable urban mobility policies and actions; the audit scheme was applied and external auditors trained. The POLY-SUMP project prepared detailed guidance on how to implement a participatory approach that engages citizens and stakeholders in a polycentric region to develop a shared vision of sustainable mobility. It was applied and tested in six regions in Europe.

To transfer the research results to practical usage, wide agreement and political support is needed, as well as communication with the public. The following conclusions can be formulated using experience of the analysed projects of this theme.

The TRANSPOWER project concludes that the European Commission and individual Member States shall expand their efforts to support local decision makers in protecting and expanding public transport by making financial means available and supporting legal amendments. Increased efforts should also be made to support planners, operators and decision makers in enhancing public transport by providing forums for exchanges and knowledge transfer.

The CURACAO project compiles recommendations to national governments, which are formulated to develop a clear national transport strategy. This strategy should also highlight the potential benefits of road-user charging as a tool for demand management at local and national levels. The application of road-user charging schemes should also be considered as a part of a wider strategy involving the internalisation of external costs, and the adjustment of road and vehicle taxation systems. National governments are recommended to ensure the provision of appropriate legislation, which will enable city, local and regional authorities to implement road-user charging and the policy instruments that will complement it.

Recommendations include publishing guidance for authorities interested in considering road-user charging as a policy tool. There is also a need for governance structures that enable city authorities to implement road-user charges (and the policy instruments that complement them), and to collect and use scheme revenues in accordance with policy objectives. Therefore further areas of research are:

- cities to carry out feasibility studies addressing ways to reduce congestion and environmental impacts including road-user charging options, and to support research and demonstration projects that specifically address key issues (e.g. acceptability, requirements for effective implementation, and economic and equity impacts);
- educational campaigns, training schemes and toolkits explaining the rationale behind road-user charging as one valid option in the range of measures available to transport planners and encouraging the participation of citizens and stakeholders in finding out approaches to tackling sustainable mobility issues;
- research on standardisation and interoperability of road-user charging systems and technologies.

Under the NICHES project, different urban transport experts elaborated the following policy recommendations addressed to EU policy makers:

- Provide clear EU-wide definitions of sustainable urban transport and clean vehicles.
- Strengthen the status of soft measures in EU policies. Soft measures have proven to be cost-efficient and effective tools to tackle urban transport problems. Nevertheless, they often seem to be neglected in discussions about the future direction of EU policies in the field of urban transport.
- Encourage development of Sustainable Urban Transport Plans (SUTP – now known as SUMP).
- Foster EU-wide promotion of and training on sustainable urban transport.
- Continue support for EU-wide networking activities. A continued and stable support for thematic networks with a long-term perspective is recommended as an efficient way to promote the exchange of experiences.
- Support standardisation activities for clean vehicles and road pricing. NICHES experts identified some areas related to the innovative concepts, where standardisation is lacking and poses barriers to the uptake of clean vehicles and roadpricing schemes. The European Commission should support standardisation activities in the following areas:
  - Standards for emission checks for clean vehicles to gain consistent results in Europe and to foster clean-vehicle uptake.
  - Standards for noise emissions of vehicles (e.g. for night delivery services).
  - Standards for road-pricing technologies to facilitate technical harmonisation and interoperability.

 Provide an adequate framework for urban road-pricing. The overarching legal framework for transport pricing is still very incomplete at the European level and relates entirely to heavy goods vehicles. The EU should, within the limitations imposed by the subsidiary principle, provide an enabling legislation for urban road-pricing. This also requires addressing privacy concerns related to necessary monitoring and control within urban road-pricing schemes. The EU should also continue work on the provision of a common methodology on charging.

The 'New and Innovative Concepts for Helping European Transport Sustainability – Towards Implementation' project (NICHES+, 2011), which further developed the NICHES project, generated the following policy recommendations:

- A guide book on quality standards for interchanges should be prepared. There should be different quality levels for interchanges to help cities, operators and authorities realise the concept more easily. Similar initiatives already exist (e.g. UK Golden Standard). The guide book should consider that introducing the same standards may cause equity problems (different national incomes, different national regulations, etc.).
- Motivating measures should be introduced to make sustainable modes easier to implement. So the European Commission should elaborate new/innovative taxation rules and traffic regulations in a way that sustainable and soft modes enjoy priority against cars, which is an easy and cheap solution.
- People still do not know the extent to which the external cost of transport puts pressure on the public budget. Car users are the largest contributor to these costs. The European Commission should initiate a campaign on public transport and soft ('sustainable') modes of transport causing a better modal share.
- Stressing the environmental and health benefits of cycling and walking is one of the most effective promotional measures for those modes. An appropriate solution would be to include these issues in the curriculum of primary schools, so that students would be educated in this issue from an early age.

The 'Sustainable Planning & Innovation for biCYCLES' project (SPICYCLES, 2008) discovered that the involvement of stakeholders were key in achieving almost all the specific measures of the project. Stakeholders also helped to establish plans and platforms so that work can continue beyond the project period.

Overall, the study demonstrated that the biographical interface of migration (moving to a new place of residence or place of work) should attract more attention within a comprehensive mobility management. It requires looking for strategies on how people with a latent readiness can be addressed specifically to a behaviour change, if possible even before the move.

The results of the research projects indicate that further adjustment of the national legislation is needed, especially regarding definition of the SUMPs and their structure and methodology of preparation. Also some particular policy packages need legislation changes in some EU Member States (e.g. the definition of car-free zones, possibilities for local governments to collect road-user charges). Tendering processes represent another problem, especially for innovative measures and technologies. The EU can contribute to ensuring a smoother implementation of research results into practice by further standardisation of regulations relating to IT technologies, fuels and propulsion systems, and by the development of best practice guidance and support for the exchange of experience.

Raising awareness of SUMPs among all relevant stakeholders seems to be a key success factor for further development of these plans in European urban areas. There is an important European initiative that might contribute to this task. The web pages at www.eltis.org were created more than 10 years ago and they have become Europe's main observatory on urban mobility. There is a dedicated section on mobility plans that includes an explanation of the SUMP concept, process and guidelines, and a database of European cities involved in EU activities to promote and apply the concept of an SUMP (including, in many cases, a web-link to their urban mobility and transport plan).

#### 3.7 Urban land use

#### 3.7.1 Preliminary recommendations

The need to combine urban and transport planning has been proven. However, an integrated approach including user behaviour (and how it is influenced), new smart technologies and pricing is yet to be studied in combination. The 2011 Transport White Paper acknowledges that demand management and land-use planning can reduce traffic volumes. However, it is also directly connected to Urban Mobility Planning and the development of new strategies that can stimulate a shift towards cleaner and more sustainable transport modes, such as walking, cycling, public transport, and new patterns for car use and ownership. This planning concept highlights that urban mobility is primarily about people. Therefore, it emphasises citizen and stakeholder engagement, as well as fostering changes in mobility behaviour.

#### 3.7.2 Research environment and development

Under this sub-theme, 11 research projects were analysed – nine of them were financed by various European programmes and two of them by a national programme. Table 3-7 summarises projects included in this analysis, their duration and source of funding.

The majority (six projects) are concentrated between 2000 and 2005, funded under the 5<sup>th</sup> Framework Programme and, therefore, have a similar emphasis. Moreover, five were funded under the 'city of tomorrow and cultural heritage' initiative. Their major concern has been to highlight the connection between urban land use and travel/transport needs, as well as the positive (negative) impacts of combined (and not) planning.

Tab	le 3	-7	Projects	identi	fied	under	the	urban	land	use	sub	-theme
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Project acronym	Project name	Project duration	Source of funding
TRANSPLUS	TRANSport Planning, Land Use and Sustainability	04/2000-12/2003	FP5 EESD KA4 – City of Tomorrow and Cultural Heritage
SCATTER	Sprawling Cities And Transport: from Evaluation to Recommendations	01/2001-09/2004	FP5 EESD KA4 – City of Tomorrow and Cultural Heritage
ASTRAL	Achieving Sustainability in Transport and Land Use	05/2001-12/2003	FP5 EESD KA4 – City of Tomorrow and Cultural Heritage
Bahn.Ville	Promoting a rail oriented urban development approach for urban regions in Germany and France	12/2001-10/2004	PREDIT 3: G.O.1 – Mobility, territories and sustainable development (Operational Group 1)
ARTISTS	Arterial Streets towards Sustainability	12/2001-11/2004	FP5 EESD KA4 – City of Tomorrow and Cultural Heritage
PLUME	Planning and Urban Mobility in Europe	11/2002-05/2005	FP5 EESD KA4 – City of Tomorrow and Cultural Heritage
N/A	The Urban Transport Benchmarking Initiative	07/2003-07/2006	DGTREN – Energy & Transport DG – Miscellaneous projects
SNOWBALL	Demonstration, Take-Up and Further Dissemination of Sustainable Integrated Planning Methods in European Cities	01/2006-12/2008	IEE
PLUREL	Peri-urban Land Use Relationships – Strategies and Sustainability Assessment Tools for Urban – Rural Linkages	06/2007-06/2010	FP6-SUSTDEV – Sustainable Development, Global Change and Ecosystems – Priority Thematic Area 6 (PTA6)
Urbaging	Designing urban space for an ageing society	06/2007-06/2009	Switzerland NRP 54 – Sustainable Development of the Built Environment (National Research Programme 54)
IFPLUT	Integrated Framework Plan for Land Use and Transportation	N/A-2016	Ireland – PFC – Platform for Change Transportation Strategy

In principle, the theoretical foundations have been developed through case study research which, on the one hand allowed for a deeper understanding of issues at stake, but on the other hand, set questions with respect to the transferability of the findings.

A central challenge has been the growth of urbanisation and how to address transport planning in the outer-urban metropolitan areas (e.g. the 'Sprawling Cities And Transport: from Evaluation to Recommendations' project (SCATTER, 2004)). The phenomenon may not be handled only by initial approaches to large, medium or small size cities and may require the provision of indicators as in the case of the Urban Transport Benchmarking Initiative (2006), which provided a practical tool supporting cities in identifying changes for improving the performance of their urban transport systems. It does so by comparing them with those of other cities, understanding the differences and identifying best practice. A later research effort ('Peri-urban Land Use Relationships – Strategies and Sustainability Assessment Tools for Urban – Rural Linkages' (PLUREL, 2007-2010)) tried to model the phenomenon and found limitations due to several sources that may influence the result.

A key recurring outcome of the research has been the need to involve several stakeholders as well as governance and institutional issues. Best practice, experiments concerning the transfer of best practice, the creation of networks throughout Europe (and the world) in support of gaining and exchanging experience has been at the heart of most efforts.

Land-use research is now also including the needs of the older generation, and how to create and develop urban planning in a way that supports the active participation and mobility of all generations (e.g. the Urbaging Project).

#### 3.7.3 Research activities and outcomes

The most recent project in the sub-group shows how research in this sub-theme is now adopted by national authorities. It is also an indication of moving towards Urban Mobility Plans and considering Integrated Urban Development Plans as indicated in the 2011 Transport White Paper. Pioneers in this approach include 'Promoting a rail oriented urban development approach for urban regions in Germany and France' (Bahn-Ville, 2001-2004) funded by Predit (French Government). However, an integrated approach to the research is missing.

Within the group of projects related to the city of tomorrow and cultural heritage, the topics studied included:

- 'TRANSport Planning, Land Use and Sustainability' project (TRANSPLUS, 2003) provided case studies with respect to land use and transport policies, assessed ways of combining policies, introduced assessment indicators and criteria for land use, and promoted land use and transport planning frameworks.
- SCATTER tackled the issue of urban sprawl, in particular in the context of cities implementing new suburban public transport services.
- 'Arterial Streets towards Sustainability' (ARTISTS, 2004) concerned the design of arterial streets, as they present

a particular challenge to sustainable urban planning. The scope was to improve the basis for decisions regarding the reconstruction of arterial streets, taking into account a broad set of social, economic and environmental factors.

- 'Planning and Urban Mobility in Europe' (PLUME, 2005) concerned the transfer of innovation in the field of planning and urban mobility from the research community to end users in the cities of Europe to improve urban quality of life.
- 'Achieving Sustainability in Transport and Land Use' (ASTRAL, 2003) had the scope of assisting national governments, cities, non-governmental organisations, interest groups and individuals in obtaining maximum benefit from the research undertaken.

Two examples of projects related to the involvement of multiple stakeholders as well as governance and institutional issues are:

- Bahn Ville is a project that looked into the exchange of experience between France and Germany in urban planning and development, especially with respect to rail or urban/ peri-urban light rapid transit as this provides a new way to develop cities.
- 'Demonstration, Take-Up and Further Dissemination of Sustainable Integrated Planning Methods in European Cities' (SNOWBALL, 2008) elaborated mostly on the work that was carried out by ECOCITY and CIVITAS. Both used the idea of integrated urban planning, and focused mainly on the development of criteria and concepts and their demonstration. SNOWBALL used actual implementation as promising examples for other cities and setting up structures for further dissemination.

The current research activity under this sub-theme is a nationally funded project 'Integrated Framework Plan for Land Use and Transportation' (IFPLUT) undertaken in Dublin, Ireland, which aims to coordinate efforts across all involved when addressing urban areas.



## 4 Further urban mobility projects

In addition to the projects that have been mentioned in the preceding sections, a number of further projects have been identified within TRIP that are of potential significance for the theme, but which fall outside of the criteria for selection for the analysis (e.g. ongoing projects that have not delivered final reports from which project conclusions and recommendations could be ascertained). Table 4-1 presents the acronyms and titles of some of these relevant additional projects.

Project acronym	Project name	Project duration
MODERN	Mobility, Development and Energy Use Reduction	2008-2012
MEDIATE	Methodology for Describing the Accessibility of Transport in Europe	2008-2010
METPEX	A MEasurement Tool to determine the quality of the Passenger EXperience	2012-2015
SUCCESS	Smaller Urban Communities in Civitas for Environmentally Sustainable Solutions	2005-2009
STRAIGHTSOL	STRAtegies and measures for smarter urban freIGHT SOLutions	2011-2014
FURBOT	Freight Urban RoBOTic vehicle	2011-2014
VIAJEO PLUS	International Coordination for Implementation of Innovative and Efficient Urban Mobility Solutions	2013-2016
OPTICITIES	Optimise Citizen Mobility and Freight Management in Urban Environments	2013-2016
i-TRAVEL	Service Platform for the Connected Traveller	2008-2009
CONDUITS	Coordination of Network Descriptors for Urban Intelligent Transportation Systems	2009-2011
STADIUM	Smart Transport Applications Designed for Large Events with Impacts on Urban Mobility	2009-2013
i-TOUR	intelligent Transport system for Optimized URban trips	2010-2013
Enhanced WISETRIP	Enhancing Intermodality of Content, Personalised Information and Functionality of WISETRIP Network of Journey Planning Engines	2011-2014
OPTICITIES	Optimise Citizen Mobility and Freight Management in Urban Environments	2013-2016
SILENCE	Quieter Surface Transport in Urban Areas	2005-2008
ARCHIMEDES	Achieving Real Change with Innovative Transport Measures Demonstrating Energy Savings	2008-2012
RENAISSANCE	Testing Innovative Clean Urban Transport Strategies for Historic European Cities	2008-2012
CITYHUSH	Acoustically green road vehicles and city areas	2010-2012
RIVAS	Railway Induced Vibration Abatement Solutions	2011-2013
Green EMOTION	Green eMotion	2011-2015
FURBOT	Freight Urban RoBOTic vehicle	2011-2014
CATS	City Alternative Transport System	2012-2013

#### Table 4-1 Additional projects within TRIP of relevance to Urban Mobility theme

Project acronym	Project name	<b>Project duration</b>
CITYMOBIL 2	Cities demonstrating cybernetic mobility	2012-2016
ZEEUS	Zero Emission Urban bUs Systems	2013-2017
CIVITAS ELAN	Mobilising citizens for vital cities Ljubljana – Gent – Zagreb – Brno – Porto	2008-2012
CIVITAS DYN@MO	CIVITAS DYN@MO	2012-2016
TIDE	Transport Innovation Deployment for Europe	2012-2015
CIVITAS 2MOVE2	New forms of sustainable urban transport and mobility	2012-2016
SOLUTIONS	Sharing Opportunities for Low carbon Urban TransporTatION	2013-2016
ISOTOPE	Improved Structure and Organisation for Urban Transport Operations of Passengers in Europe	1995-1997
MOMENTUM	Mobility Management for the Urban Environment	1996-1999
QUATTRO	Quality Approach in Tendering Urban Public Transport Operations	1996-1998
TRANS-AFRICA	Promoting Public Transport in Africa	2008-2010
HCV	Hybrid Commercial Vehicle	2010-2013
CATS	City Alternative Transport System	2012-2013
MOSIAC	Materials Onboard: Steel Advancements and Integrated Composites	2012-2015
3iBS	The Intelligent, Innovative, Integrated Bus Systems	2012-2015
SESAME	Derivation of the Relationship between Land-Use, Behaviour Patterns and Travel Demand for Political and Investment Decisions	1996-1998
TRANSLAND	Integration of Transport and Land-Use Planning	1999-1999
PROPOLIS	Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability	2000-2003
CLOSER	Connecting LOng and Short-distance networks for Efficient tRansport	2010-2012
OPIUM	Operational Project for Integrated Urban Management	1996-1998
CAPTURE	Cars to Public Transport in the Urban Environment	1996-1999
ICARO	Increase of Car Occupancy through Innovative Measures and Technical Instruments	1997-1999
URBAN TRACK	Urban Rail Infrastructure	2006-2010
NODES	New tOols for Design and OpEration of Urban Transport InterchangeS	2012-2015

Table 4-1 (continued) Additional projects within TRIP of relevance to Urban Mobility theme

## 5 Conclusions and recommendations

The review of research under the theme of Urban Mobility has concentrated on seven sub-themes under the heading in addition to an overall theme review:

- accessibility;
- urban freight transport;
- urban intelligent transport systems;
- · low carbon transport technologies;
- sustainable public transport;
- Sustainable Urban Mobility Plans (SUMPs);
- urban land use.

The overall conclusions and recommendations (as presented in Section 2.5 of this report) are that significant research outputs are being generated on urban mobility and are largely addressing the main policy objectives in this area, if not to the degree to achieve the 'step change' in urban mobility that is needed. In terms of taking this research area forward with the aim of further improving the outputs, the following recommendations are made:

- it is important to continue to develop and promote an integrated approach to urban mobility research – priority should be given to projects looking to work across different transport modes and addressing a combination of challenges;
- develop and trial new mobility concepts applying and integrating technologies and innovation in new ways with the aim of achieving a 'step change' in urban mobility patterns;
- tackle institutional and implementation issues as part of the research – this will help ensure solutions are brought closer to use in practice following the work;
- engage key stakeholders from the outset work with key implementers and innovators to help uptake of the ideas beyond the project;
- continue with the core technology research in intelligent transport systems, vehicles and fuels – providing the building blocks for an innovative, integrated and comprehensive approach to urban mobility, but seeking new solutions appropriate for the urban context, such as urbanspecific delivery vehicles.



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## 7 Glossary

#### The following abbreviations have been used in this review.

CAS	Collision avoidance system
CIVITAS	City-Vitality-Sustainability (Cleaner and Better Transport in Cities Initiative)
CNG	Compressed natural gas
dB (A)	decibel (A-scale)
DMF	Design and monitoring framework
DSP	Delivery and servicing plan
DSRC	Dedicated short range communication
ERA-NET	European Research Area Networking Programme
ETCS	European train control system
ETS	Emissions Trading System
FCD	Floating car data
FCH	Fuel Cell and Hydrogen Joint Undertaking
FP7	Framework Programme 7 of the European Commission – (also FP4, FP5, FP6)
GHG	Greenhouse gas
I2V	Infrastructure to vehicle (communications)
IEE	Intelligent Energy Europe
IoT	Internet of things
IPCC	Intergovernmental Panel on Climate Change
ITS	Intelligent transport system
LFDP	Local freight development plans
LNG	Liquefied natural gas
NRP	National Research Programme (Switzerland)
PIARC	World Road Association
PPP	Public-private partnership
RFID	Radio frequency identification
RTD	Research and technology development
RRS	Road restraint system
SULP	Sustainable Urban Logistic Plan
SUMP	Sustainable Urban Mobility Plan
TEN-T	Trans-European Network – Transport
TRIP	Transport Research and Innovation Portal
UCC	Urban Consolidation Centre
UNFCCC	United Nations Framework Convention on Climate Change
V2I	Vehicle to infrastructure
V2V	Vehicle to vehicle
V2X	Vehicle to everything
ZEL	Zero-emission urban logistics

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