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Evaluation and assessment of likely benefits of the Harmonised Research Programme

D18

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AUTHORS

Name	Institution
Benjamin Heydecker	UCL
Francesca Medda	UCL
JD Addison	UCL

Contributors

Name	Institution
RE Allsop	UCL
MGH Bell	Imperial
Christine Buisson	IFSTTAR
Winnie Daamen	TU Delft
Yun-Pang Flötteröd	DLR
Pierre-Yves Gilliéron	EPFL
Serge Hoogendoorn	TU Delft
Nick Hounsell	UoS
Jun Hu	Imperial
Jean-Patrick Lebacque	IFSTTAR
Jean-Baptiste Lesort	ENTPE
Markos Papageorgiou	TUC
Ioannis Papamichail	TUC
Ioannis Kaparias	Imperial
Peter Wagner	DLR
Ben Waterson	UoS
Thalis Zis	Imperial

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Applicable Documents

Description
NEARCTIS deliverable D6: Review of the state of knowledge and capability in relevant technologies
NEARCTIS deliverable D7: Review of available case studies and related scientific knowledge
NEARCTIS deliverable D8: Identification of success, gaps and potential for improvements in traffic management applications
NEARCTIS deliverable D14: The harmonised research programme
NEARCTIS deliverable D15: Specifications and evaluation approaches for possible case studies
EU COM(2011) 808: Horizon 2020 - The Framework Programme for Research and Innovation
FELICIE: Future elderly living conditions in europe :

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Name	Organisation
Naomi Baster	PACTS
Prof MC Bell	TORG
Mark Brackstone	IOMI
Andy Emmonds	TfL

Contents

Abstract

The NEARCTIS Network of Excellence is addressing the potential for benefit directly to travellers and also to society as a whole that can be achieved by improvements to the transport system through adoption and application of information and communications technology (ICT) for use in intelligent transport systems (ITS) for cooperative traffic management. This has led to development of a Harmonised Research Programme on cooperative traffic management, with broad-based joint and separate analyses of current traffic management systems, cooperative ICT, objectives of traffic management, the state of knowledge in this area, and research needs that have already been identified.

Traffic management has moved from an isolated technical problem to a more integrated vision of widespread mobility in which multiple criteria and constraints are considered. This recognises the overarching need for cost-effective, efficient transport systems that provide a wide range of attractive choices to all members of society. At the same time, continuing advances in technology, techniques and equipment for management of road traffic provide opportunities to develop and implement novel approaches to traffic management and control. The rapid development of communications technology provides new means to collect, integrate and use information, from vehicle positioning, identification and tracking, and bi-directional communication technologies to improve performance of the transport system. This opens up a wide area for research to take full advantage of the opportunities for improvements using cooperative ICT. This can be integrated into a global vision for the transport system and can contribute to a wide range of objectives.

The objectives of research on co-operative ICT in transport were identified as part of the work of the NEARCTIS consortium through a systematic review of the major long-term challenges for the EU in traffic management. The following five key objectives of research on co-operative ICT in transport:

1. Safety
2. Environmental Impact
3. Efficiency of the Transport System
4. Traveller and System User Experience
5. Societal Impacts, Costs and Equity

These objectives are viewed as having similar priority. Although the general consensus is that safety is of particular importance, there is also agreement that it should not be considered to the exclusion of the other key areas. Instead, we suppose that innovations and developments should be considered provided that they are at least safety-neutral.

Beyond this, the following three priorities that have been set out for the forthcoming EU Horizon 2020 programme:

1. Societal challenges
2. Industrial leadership
3. Excellent science

The seven research themes under which the NEARCTIS Harmonised Research Programme was developed and presented in D14 are:

1. Increased availability of mobile communications
2. Increasing data availability
3. Improved modelling at all scales
4. The need for communication between autonomous systems
5. An understanding of the consequences of interactions at various levels
6. Achieving effective large-scale management of transport systems and their efficient usage
7. Support for policy developers and decision makers.

The substance of the present deliverable D18 is to evaluate and assess the likely benefits of the Harmonised Research Programme that is set out in deliverable D14. To achieve this, each of the seven research themes is assessed against each of the five NEARCTIS objectives and three Horizon 2020 priorities. The analysis is also summarised from the perspective of these objectives and priorities to identify the likely contributors to each of them. This dual viewpoint on potential benefits provides an effective summary of likely benefits of the proposed research.

Considering each of the research themes in turn generated a profile of likely contributions across the Harmonised Research Programme. The systematic approach developed here explores the potential contributions of cooperative ICT to traffic management and control. This led to formulation of an agenda generated a profile of likely contributions of research undertaken within the Harmonised Research Programme. A particular benefit of this is to identify which research themes is likely to contribute most to each of the objectives and priorities so that where specific requirements can be identified, research can be undertaken accordingly.

1. Introduction

The Harmonised Research Programme as presented in D14 is one of the key outcomes of the NEARCTIS project. The current document provides and evaluation and assessment of the expected impact of the programme against a number of criteria. The criteria are the objectives of co-operative ICT identified as part of the development of D14 and the priorities of the EI Horizon 2020 programme. In this chapter the framework of the Harmonised Research Programme, the objectives for co-operative ICT and the priorities of Horizon 2020 are reviewed. The links between the research themes of the Harmonised Research Programme and the proposed case studies presented in D15 are also considered. This approach provides complementary view on the value of research drawing, respectively, from the opportunities identified in the research themes and the requirements identified in the case studies.

The next three chapters are devoted to the assessment of the programme. Chapter 3. contains a detailed discussion of the expected contributions both positive and negative of each research theme to the NEARCTIS objectives and the Horizon 2020 priorities. It shows how all themes contribute directly and indirectly to all the criteria. Chapters 4. and 5. provide an alternative view showing how the programme as a whole contributes to each of the NEARCTIS objectives(Chapter 4.) and the priorities of Horizon 2020(Chapter 5.).

1.1. The Harmonised Research Programme

The Harmonised Research Programme presented in deliverable D14 is a framework for research on co-operative ICT in transport: the particular benefit of establishing this is that proposed projects can be assessed and related to each other in respect of their combined coverage and their complementarity. The framework has 5 distinct dimensions of classification of research on co-operative ICT. These are:

1. Key objectives
2. Research themes
3. Areas of expertise
4. Areas of traffic management
5. Opportunities for innovative contribution.

The resulting Harmonised Research Programme is organised according to the research themes of the framework. Within each theme, research is introduced, the underlying motivation explored and the premises on which it is based elucidated, including some of the major issues to be addressed. The expected outcomes of researching that theme identify some of the areas to be addressed in order to develop and exploit the potential benefits of co-operative ICT for traffic management. The agenda presented is extensive but remains open to extension and enrichment from complementary research ideas.

The 7 research themes that are addressed are:

1. Increased availability of mobile communications
2. Increasing data availability
3. Improved modelling at all scales
4. The need for communication between autonomous systems
5. An understanding of the consequences of interactions at various levels
6. Achieving effective large-scale management of transport systems and their efficient usage
7. Support for policy developers and decision makers.

Considering each of these in turn led to the formulation of a programme of research that addresses a broad agenda. By considering this as a whole, it could be harmonised in the sense that interrelationships among these themes could be recognised and explored. This will support the research effort by identifying commonalities and opportunities for cross-linkage, and by identifying the complementarities that will enhance the value of each contribution.

1.2. Objectives of the research programme

The evaluation of the research programme presented in D14 is against the primary objectives of the research programme identified there and also against the priorities of Horizon 2020. Each of the themes around which the Harmonised Research Programme is organised was assessed individually for their contributions either directly or *via* research from other themes.

The objectives of research on co-operative ICT in transport were identified in D14 through a systematic review of the major long-term challenges for the EU in traffic management. The following five **key objectives** of research on co-operative ICT in transport:

1. **Safety**
   The social, economic and environmental cost and consequences of unsafe systems means that major effort is devoted to improving the safety of transport systems not only for users but also for those involved in their operation and maintenance. The European Commission has devoted considerable resources to facilitating and encouraging road safety. An understanding of the implications for safety of research is therefore an essential part of the Harmonised Research Programme.

2. **Environmental Impact**
   Transport systems have a deep and lasting impact on the environment, locally, regionally and globally. A number of issues arise relating to the environmental impact of travel and transport systems. There is a need to improve fuel consumption, pollution, noise emissions and air quality. Better traffic management and control may advance these goals. In particular the use of more, better and more timely data can facilitate inclusion of environmental effects to influence traffic control decisions. With knowledge of downstream traffic conditions, opportunities will arise to promote these objectives by proving informing driver that will enable better engine management and trajectory control that will smooth traffic flow and eliminate stop-go traffic.

   Encouraging switching travel to use less polluting modes of travel in particular, and working towards truly inter-modal traffic and transport management is an important mechanism for this objective.

3. **Efficiency of the Transport System**
   The purpose of the transport system is to facilitate the movement of goods and people from their origins to their desired locations. It is important that this be done effectively and efficiently, making good use of the resources available and with external effects that are managed and, where they are adverse, limited so far as is possible. Transport and traffic management aims to ensure that infrastructure is used efficiently, and that users of the system and others who are affected are not subject to excessive and avoidable cost.

   It is also important to identify where additional infrastructure resources, management resources and regulation will bring worthwhile additional benefits.

4. **Traveller and System User Experience**
   Many opportunities arise for improving user experience. These include:

   - Improved traffic conditions as a result of co-operative management.
   - The effect and improvement of bus priority systems to encourage modal switching.
   - Warning of incidents, hazards and other influences on travellers.
   - Improved safety and security of transport systems and their usage.
   - Improved and more efficient freight and goods distribution. With the rise of online shopping and home delivery these issues are expanding to a greater scale.
   - Improved, more reliable and up to date information on the state of the transport system and the traffic using it.

   Other issues that arise are the effect on user behaviour and choices in using the transport system of access to improved and more up to date information, the impact of instantaneous communication, and also the need for high-level reliable information.

5. **Societal Impacts, Costs and Equity**
   The wider impacts of co-operative traffic management give rise to a number of issues. Topics and issues that arise in this include:

- The effects of improvements in vehicle tracking. Road user charging moving beyond charging for consumption through fuel duty then becomes more practical. There are also implications for enforcement of traffic regulations and wider enforcement of traffic and other laws. Commonplace vehicle tracking also raises issues of privacy.
- Improved accessibility for older drivers, and an increased comfort for all making driving safer.
- Payment for the costs of co-operative systems. Some benefits will be immediately clear to users but others may be less clear and in some case the benefits may accrue to others and elsewhere in society as a whole.

These objectives are viewed as having similar priority. Although the general consensus is that safety is of particular importance, there is also agreement that it should not be considered to the exclusion of the other key areas. Instead, we suppose that innovations and interventions should be considered provided that they are at least safety-neutral. Thus an innovation or intervention could be justified on grounds other than safety benefit provided that it is not expected to be detrimental to safety. Further objectives that are also relevant include accessibility, economic return, livability and sustainability, which can be incorporated within the five key objectives listed above.

The priorities set out for the Horizon 2020 programme are:

1. **Societal Challenges**
   Horizon 2020 reflects the policy priorities of the Europe 2020 strategy and addresses major concerns shared by citizens in Europe and elsewhere. A challenge-based approach will bring together resources and knowledge across different fields, technologies and disciplines, including social sciences and the humanities. This will cover activities from research to market with a new focus on innovation-related activities, such as piloting, demonstration, test-beds, and support for public procurement and market uptake. It will include establishing links with the activities of the European Innovation Partnerships (EIT).
2. **Industrial Leadership**
   The Competitive Industries objective aims at making Europe a more attractive location to invest in research and innovation, by promoting activities where businesses set the agenda. It will provide major investment in key industrial technologies, maximise the growth potential of European companies by providing them with adequate levels of finance and help innovative SMEs to grow into world-leading companies. Horizon 2020 will:
   - build leadership in enabling and industrial technologies, with dedicated support for ICT, nanotechnologies, advanced materials, biotechnology, advanced manufacturing and processing, and space, while also providing support for cross-cutting actions to capture the accumulated benefits from combining several Key Enabling Technologies;

- facilitate access to risk finance;
- provide Union wide support for innovation in SMEs.

Leadership in enabling and industrial technologies: will support the development of technologies underpinning innovation across a range of sectors, including ICT and space. Horizon 2020 will have a strong focus on developing European industrial capabilities in Key Enabling Technologies (KETs)

Small and medium-sized enterprises (SMEs) will be encouraged to participate across Horizon 2020 programmes through a new dedicated SME instrument. It aims to fill gaps in funding for early-stage, high-risk research and innovation by SMEs as well as stimulating breakthrough innovations. It is expected that through this integrated strategy around 15%, or €6.8 billion, of the total combined budgets of the 'Tackling societal challenges' Specific Programme and the 'Leadership in enabling and industrial technologies' objective will be devoted to SMEs.

3. **Excellent Science**
Horizon 2020 will raise the level of excellence in Europe's science base and ensure a steady stream of world-class research to secure Europe's long-term competitiveness. It will support the best ideas, develop talent within Europe, provide researchers with access to priority research infrastructure, and make Europe an attractive location for the world's best researchers. Horizon 2020 will:

    - support the most talented and creative individuals and their teams to carry out frontier research of the highest quality by building on the success of the European Research Council (ERC);
    - fund collaborative research to open up new and promising fields of research and innovation through support for Future and Emerging Technologies (FET);
    - provide researchers with excellent training and career development opportunities through the Marie Curie Actions;
    - ensure Europe has world-class research infrastructures (including e-infrastructures) accessible to all researchers in Europe and beyond.

1.3. Case Studies: D15

The Harmonised Research Programme presented in D14 identified research needed to ensure that co-operative transport management achieves its full potential. The wide range of themes identified and the diverse research requirements included there illustrated the ambition for co-operative transport management. The programme lays out what needs to be accomplished to achieve full-scale effective co-operative transport management. Progress towards that goal will be made by work on imaginative, ambitious case studies motivated by the programme. The third activity of WP2 was the "Identification and pre-assessment of possible new sites and systems". Based on the analysis of the first and second of these activities and the elaborations within

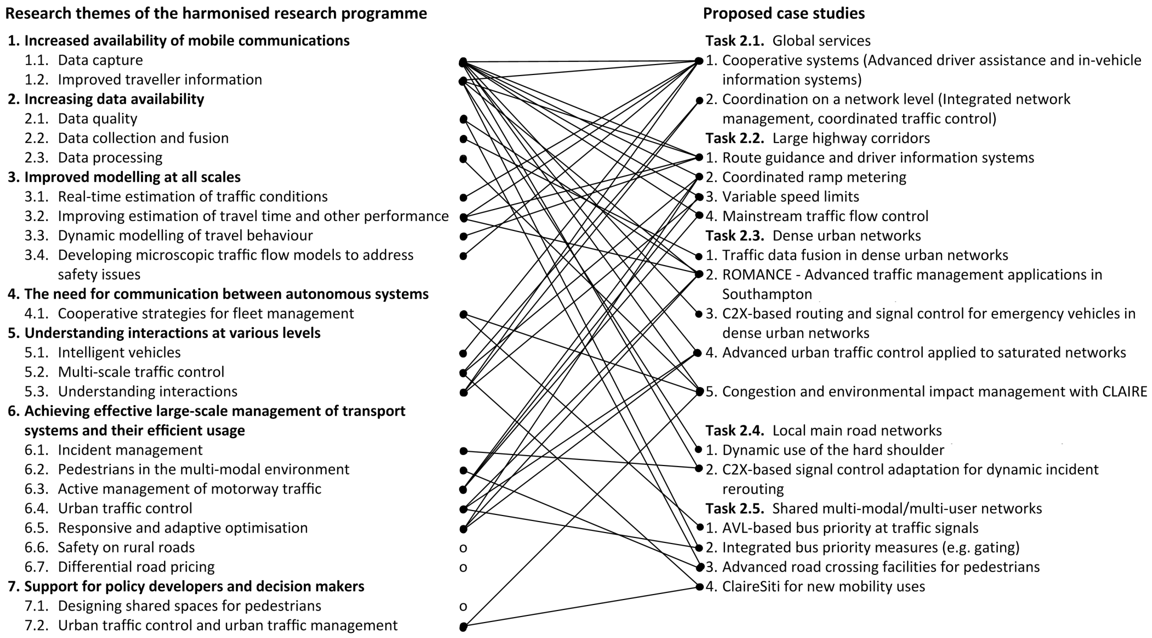

Figure 1.1: Links between themes of the Harmonised Research Programme of D14 and the case studies of D15

WP1, this third activity selected and focused on specific sites and systems for case studies. D15 proposes specific research, development and implementation possibilities for each selected site that are deemed to improve and advance the state-of-the-art and best practice in the related traffic management area.

The development of the Harmonised Research Programme was influenced by the early work in Work Package 2 on the identification and evaluation of case studies. Development of the Harmonised Research Programme was influenced by the NEARCTIS Deliverable D7, which reviewed available case studies and related scientific knowledge, and in particular D8, which identified successes, gaps and potential for improvements in traffic management application areas. Deliverable D15 on specifications and evaluation approaches for possible case studies from WP2 was undertaken with knowledge of the Harmonised Research Programme from D14. The case studies are organised round areas of traffic management, the fourth of the five dimensions of classification identified in D14 and listed earlier. The range and ambition of the case studies proposed will stimulate and use research from all of the themes identified in D14. These early case studies will in turn provides further information on likely benefits and suitable evaluation measures for co-operative ICT in transport and suggest further research from the various themes. Figure 1.1 based on Figure 1.1 from D15 illustrates the links between the case studies and the research themes of D14. This shows not only the comprehensive nature of the case studies proposed but confirms that research and knowledge from many themes will be required to achieve effective co-operative traffic management with its varying and at times competing objectives.

2. Methodology of our work towards D18

2.1. Introduction

The definition of the Harmonised Research Programme has been a fundamental task for the NEARCTIS project. The activities in Work Package 1 (WP1) have elaborated the common view of the state of the art, identified the fields of excellence among the partners and delineated the gaps in knowledge. This led to specification in Deliverable D14 of a Harmonised Research Programme that addresses the future research requirements in the field of co-operative information and communication systems as applied in the form of intelligent transport systems. The allocation of resources to implement a research programme of this kind depends on evaluation of the range and extent of the benefits that are likely to arise from it. The substantial importance of this research together with these benefits will be fundamental to the adoption of the research. This makes the preparation of the present deliverable a challenge for the entire consortium; therefore, a systematic approach and methodology for the evaluation of the Harmonised Research Programme is needed.

This section sets out the methodology that was developed and adopted for this purpose. It started from analysis of each of the research themes of the Harmonised Research Programme with reference to the objectives that had been identified within NEARCTIS and also the priorities of the Horizon 2020programme. The resulting analysis of the themes was developed through a process of presentation, discussion and criticism that involved both core partners and practitioner experts.

2.2. Methodology

The methodology was designed with the intention to achieve a final evaluation of the Harmonised Research Programme that is systematic and adequate. In particular, it should be *extensive*, *agreed* and *balanced*. The evaluation should be *extensive* in representing a comprehensive range of objectives that are relevant to co-operative ICT. It should be *agreed* among the partners, in that it draws on their collective expertise, and engages their current and future interest, and approved by representatives of the practitioner community. Finally, it should be *balanced* between coverage of a broad spectrum and focus on particular interests. It should consider present necessities without neglecting future needs. It should make full use of the available knowledge and objectives, but at the same time be open to future ones. The methodology that was adopted considers all of these in evaluating the Harmonised Research Programme.

To ensure an extensive, agreed and balanced evaluation of the Harmonised Research Programme, a phased approach was developed, which is illustrated in Figure 2.1. This involved planning and undertaking a series of consultations of members of the NEARCTIS consortium and associated

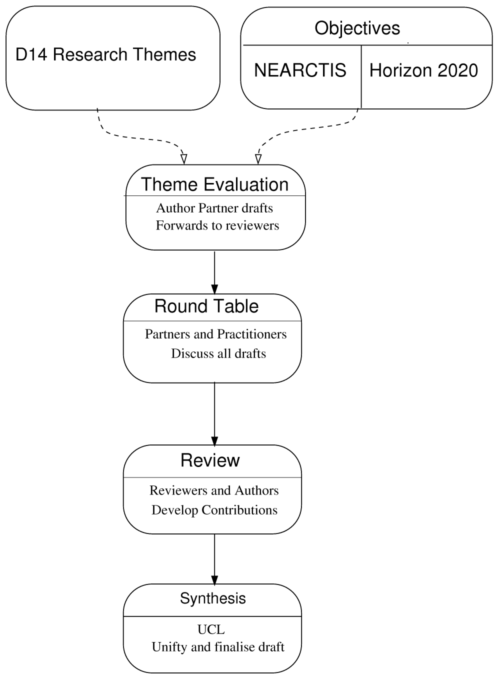

Figure 2.1: D18 Creation Process

practitioners, each building on the results of the previous one. The process was phased in the sense that each of the consultations included a call for contributions that was followed by assimilation of the responses, synthesis of the resulting information and internal dissemination of the results. On the basis of their contributions to the seven themes of the Harmonised Research Programme, each partner was invited to draft an evaluation of one or other of the themes with reference to the five objectives of NEARCTIS and the three priorities of Horizon 2020. The first phase of internal dissemination of the Harmonised Research Programme gave each partner an opportunity to consider the programme as a whole and to develop their point of view on the topic of the consultation. Subsequently, after the receipt of these contributions, they were assimilated and circulated to all partners for consideration and comment.

After a preliminary draft of material on evaluation of the Harmonised Research Programme had been circulated to NEARCTIS partners for information and comment, it was discussed at a round-table meeting convened in London at which all core partners of the consortium were represented. The membership was complemented by practitioners who were invited to represent specific expertise in respect of one or other of the NEARCTIS objectives. The purpose of this round-table meeting was to refine and consolidate the draft evaluation of the Harmonised Research Programme. This provided partners with an opportunity to review and comment on the draft and so to contribute to its finalisation. This process recognised the substantial potential value in developing existing material to address objectives in ways that become apparent only in the context of the full draft. To facilitate a balanced approach, for each theme a second partner was asked to lead the discussion on the evaluation of that theme based round the submitted contribution. Through this, we achieved a fuller, more rounded and balanced evaluation in the Harmonised Research Programme in the context of the framework that was developed to establish it. This process benefited considerable from consultation with practitioners and from their written contributions following the round table that have been assimilated into the present evaluation.

Following on from the open discussions at the round table meeting, each partner was designated to review in detail one or other of the research theme evaluations. This reviewing partner was then responsible for discussing the material with the authoring partner who contributed it. This enabled them to develop an agreed version in light of discussion at the round table and their more detailed review. During this phase, the topic of the consultation was developed in accordance with the inferred common view.

The resulting evaluations of the themes of the Harmonised Research Programme were then collated and drawn together into a first draft of the present deliverable. This first draft was then circulated to partners for their comment and further contributions before being finalised and submitted. In order to ensure a coherent view of the evaluation of the Harmonised Research Programme, the detailed evaluations for each theme were used as a basis of a synthesis of the evaluation for each of the objective of NEARCTIS and each of the priorities of Horizon 2020. These are presented in Chapters 4. and 5.

In summary, the adopted methodology is appropriate for the characteristics that the Harmonised Research Programme is required to have, and it adds consistency, structure and coherence to the evaluation. This approach was adopted in light of the success of the corresponding approach to generation of earlier deliverables from the NEARCTIS network of excellence.

3. The Research Themes

The organisation of the Harmonised Research Programme in seven distinct research themes was explained in Section 1.1. and the objectives against which the programme should be evaluated were presented in Section 1.2. This chapter considers each of the seven themes in turn to explore their contributions to the NEARCTIS objectives and the priorities of the forthcoming Horizon 2020 research programme.

Among these research themes, two are identified as facilitators, namely Increased availability of mobile communications, and Increased data availability. These represent primary entry points to the NEARCTIS research programme for two reasons. First, they will introduce new generations of traffic management systems that innovate beyond refinements and marginal developments of current systems. Second, this aligns with the philosophy of the NEARCTIS research community within the greater ITS community in its work on traffic management systems by linking from technological development to improvement of the transport system as a whole. A particular feature of these facilitators, though is that they do not in themselves promote societal objectives. Rather, they facilitate technological development of mechanisms and producers that do so.

The seven themes play, as illustrated in Figure 3.1, different roles in the overall research programme. The ultimate aim of the research programme is to contribute to a the provision of a better transport system with cooperative traffic management playing and essential role. The outcomes of the themes *Achieving effective large-scale transportsystems and their efficient usage* and *Support for policy developers, decision makers, managers and operators* will be the means by which this is delivered. A basic underlying assumption of these themes is the availability of good quality information providing view of current traffic conditions and high quality modelling to provide predictions of future traffic states to assist long term policy decisions, day to day management decisions and measures, and individual travel decisions. The two themes *Increased Availability of Mobile Communication* and *Increased Data Availability* are critical to the overall programme as they ensure that the required data is available and that there are ways of communicating information to travellers and other users of the transport system. The three themes *Improved Modelling at all Scales*, *The Need for Communication Between Autonomous Systems* and *Understanding Interactions at Various Levels* provide means by which the data is processed and proved as useful information about the transport system and its expected behaviour.

3.1. Increased Availability of Mobile Communication

The increasing availability of mobile communication offers a number of opportunities for use with co-operative systems. Many of the anticipated benefits and much of the research needed to realise those benefits are predicated on the uses and availability of mobile communications. Much of the research identified for this theme will make indirect contributions to the objectives.

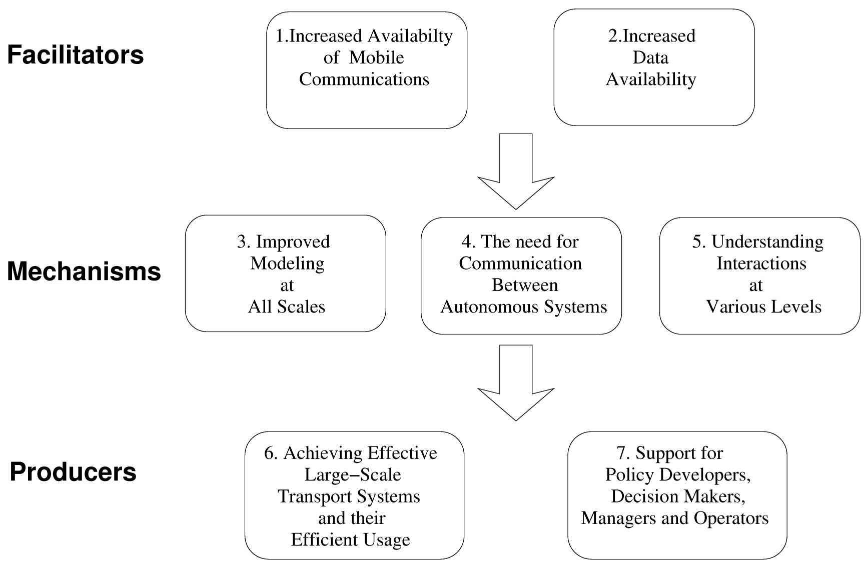

Figure 3.1: Relationships among the Seven Research Themes

In the research framework described in D14 the increased use of mobile communication, offering a number of opportunities for co-operative systems in traffic, is considered separately for different recipients. Hence, the wider use of mobile communications received by infrastructure (V2I) are predominantly concerned with the increased possibilities offered in the field of data collection; on the other hand, mobile communications received by vehicles and users (I2V and V2V) involve the potential arising from the provision of improved data and traveller information. The analysis presented considers the impacts (benefits and drawbacks) of the increased use of mobile communication in both cases with respect to a number of relevant objectives.

3.1.1. Objectives identified for NEARCTIS

Safety The increased use of mobile communication has the potential to contribute to transport safety and to change the scene in this field. Direct benefits can be expected for management and analysis from advanced data collection. These will accrue for users through provision of higher quality information and more prompt delivery. Namely, the increased use of mobile communications can facilitate the realisation of more advanced and efficient transport-safety-related services, including incident detection, warnings for accident prevention and timely emergency response. Based on the ability to accurately track and efficiently transmit the position of mobile probes, but also on the ability to effectively disseminate safety-related information to road users, a number of key applications have already been or are currently being developed (*e.g.* intersection assistance, eCall), while others are still being envisioned (*e.g.* co-operative signal control, safety systems for vulnerable road users). Moreover, mobile communications can further assist in the building of a comprehensive and accurate safety evidence base (*e.g.* more detailed automated accident records transmitted to a central database in real-time, monitoring of pedestrian trajectories to prevent collisions), allowing for a better-informed decision-making on accident mitigation measures. Additionally the prospect of providing short-term future traffic information such as road and weather conditions will also enhance safety of the user.

On the other hand, it should be noted that the increased use of mobile communications and the integration of new messages within the driver's environment could lead to increased distraction from the driving task. Appropriate human machine interface safety rules will be required to manage this. Hence, it is important that increases in availability and usage of in-vehicle ICT is accompanied by further advances in the field of human-machine interface.

Environmental Impact Mobile communications will affect the environmental impacts of travel in several ways, both direct and indirect. The effect of vehicle emissions on the local environment and population can be used within the calculation of routes to be recommended to travellers. Effective mobile communications will be required to deliver the results of this to drivers in order to influence their behaviour. We anticipate that the increased use of mobile communications will primarily have a wider range of indirect benefits for the environment. Given that mobile communications have the potential to improve transport system efficiency and customer experience, we expect that they will bring about smoother traffic flow and reduced vehicle-distance of travel through higher public transport patronage, greater use of shared vehicle systems and higher modal shares for walking and cycling, with consequent reduction in fuel consumption and emissions of pollutants and noise. Another possible application of mobile communication that could help reduce environmental impacts, is the use of software that pro-actively encourages the users to drive in an eco-friendly manner. Communications between vehicles in a stream may help to reduce breaking and acceleration waves.

An indirect impact could be the reduced noise emissions perceived by residents due to the congestion relief that will occur through increased mobile communication and result in fewer engines running in a given road and potentially fewer conflicts, which could lead to less use of the horn.

On the other hand, it should also be considered that the wider use of mobile devices and infrastructure may require greater energy consumption for their operation and greater use of natural resources for their manufacture, thus bringing about a number of collateral negative indirect impacts on the environment, which should be investigated.

Efficiency of the Transport System Together with safety and traveller experience, the efficiency of the transport system is one of the fields in which the benefits of the increased use of mobile communications are expected to be highest. The main benefits for the system will come through the ability to maintain more effective monitoring and allow for better quality of management of road networks. Concerning direct impacts, these have the potential to be delivered primarily through advances in data collection, as the use of mobile devices as vehicle and passenger probes can supply a wide range of transport data, which include measurements and counts complementing those from existing detectors and sensors (*e.g.* traffic flow counts, speed and travel time measurements), but also data previously only collected on an ad-hoc basis or not collected at all (*e.g.* concentration of pedestrians in public spaces). This data has the potential to increase transport system efficiency, either through supplying advanced traveller information and guidance to influence travellers' route and mode choice, or through feeding advanced traffic management methodologies (*e.g.* multi-modal routing and assignment algorithms). Some preliminary applications have already been developed in this direction (*e.g.* Google Traffic), with others being currently under planning and development.

Nevertheless, a number of issues potentially causing indirect adverse effects with respect to transport system efficiency still need to be addressed; these include both technological deficiencies (*e.g.* how to distinguish a mobile device user's travel mode, how to track mobile probes underground), and also methodological problems, such as dealing with conflicts and tradeoffs between user optimum and system optimum. .

Traveller and System User Experience Great benefits are expected from the increased use of mobile communications with respect to traveller and system user experience. Greater levels of information will allow better decision making on the user's side and thus promote the safe and effective use of the transport system. Given that the vast majority of users are equipped with some kind of mobile device, primarily smart-phones but increasingly also other devices, such as tablet computers and connected in-vehicle units, dissemination of sophisticated traveller information and guidance is becoming more straightforward, resulting from the collection of more advanced traffic data and complementary data from other sources such as social networks. Through mobile communications travellers have access to more advanced and customised travel services (*e.g.* real-time traffic and public transport information, multi-modal trip planning, online taxi booking, parking space finding), thus receiving better customer service. In particular, mobile communications have the potential to promote public transport as a fast, reliable, safe and comfortable travel mode (in contrast to popular belief in many cities worldwide). Mobile communication is one of the channels for the promotion of advanced traveller services. The advantage of mobile, location based services, is the real time (on the fly) information capability. They will also help to support the sustainable travel modes of walking, cycling, and shared vehicle systems by making their use easier (*e.g.* through integrating bicycle sharing in trip planning, providing information on bicycle availability, and facilitating booking of bicycles and docking stations for them).

Mobile communications can impact traveller and system user experience positively, both directly through access to transport services on-the-go, and indirectly through better transport system efficiency, better safety, and better quality of life. Nevertheless, unintended adverse effects (*e.g.* information overload) should be considered. Also more research should be carried out on how to convert the data into knowledge for decision makers and also to be given to the public to help them to make informed decisions.

Societal Impacts, Costs and Equity. The increased use of mobile communications is likely to have important positive direct and indirect benefits to society, costs and equity. Namely, connected mobile devices can offer access to personalised mobility information and services, which will be especially valuable for elderly and disabled road users. Examples of these services include dial-a-ride and multi-modal step-free-access trip planning. This will promote affordable mobility in deprived communities, thus enabling access to activities, preventing social exclusion, and ensuring equity for these social groups. Moreover, mobile communications can be a valuable tool for providing customised transport-related options to a wide range of social services (*e.g.* real-time routing for police, fire brigade, emergency vehicles).

In a broader sense, mobile communication can be a driver for facilitating sustainable and seamless mobility in urban and rural environments, thus helping to improve the quality of life. However, research should also investigate potential adverse effects of mobile communication, There are issues of conflicting advice from independent sources and of privacy. Problems of equity arising mainly from lower technological engagement of certain societal groups (*e.g.* elderly people).

3.1.2. Horizon 2020 Priorities

Societal challenges The increased use of mobile communications will have to overcome several societal challenges that will arise from its inception. More specifically, it needs to be ensured that everyone will be able to have access and use this kind of technology easily to facilitate their daily living. This means that the technology has to be affordable and not to require expensive devices for its use. Special attention should be given to making the interface design more approachable and easy to use, particularly for elderly and disabled road users.

Another significant challenge is making likely that drivers will follow the suggested route, so that some residents will not suffer more than others in terms of congestion and traffic induced noise and carbon emissions. The final and perhaps more crucial challenge that will arise, is convincing the public that there will be no intrusive use of personal data. It is probable that in order to facilitate decisions and optimisation of route assignment, the travel data of the user will be used. People should be assured that their personal information will remain anonymous and not be accessible by others.

Industrial Leadership The expected impacts from the increased use of mobile communications in the area of competitiveness are positive but mainly indirect, as the latter is a side effect rather than a goal in this case. Specifically, it is anticipated that the higher number of users from the demand side will prompt the entry of a larger number of suppliers of mobility-related online products and services into this already rapidly expanding market, thus inducing a shift from the traditional model of state-sponsored monopoly of transport products and services to a highly competitive environment. Existing examples include the various commercial providers of traffic data, as well as the many small independent developers of commercial mobility-related smartphone applications. Indirect positive impacts are anticipated with respect to SMEs due to the combined impacts of the increased use of mobile communication in terms of competitiveness and science base. SMEs are likely to benefit greatly both from a highly competitive market for online mobility products and services, which they can enter with low start-up costs, and also from a growing body of related research and innovation, in which they can play a prominent role as ”beta testers” and end users.

Excellent Science The increased use of mobile communications is likely indirectly to impact Europe’s science base positively in the field of transport, as it provides ”fertile land” for a large family of needed technological innovations, to be addressed by the European research community. This includes advanced methodological developments (*e.g.* mobile-probe-based traffic assignment algorithms).

3.1.3. Summary

An overview of the benefits and drawbacks that are likely to arise through the increased use of mobile communications is presented in the next table subject to their relation with the NEARCTIS and the Horizon 2020 priorities respectively. For the NEARCTIS objectives most have already been addressed as either strengths or weaknesses of this research theme, whereas for the Horizon 2020 opportunities and potential threats that are expected in the future due to increased mobile communication are presented.

Increased use of mobile communication	Benefits	Challenges
NEARCTIS objectives	Accident prevention Short term traffic information Lower fuel consumption and pollutant emissions Advanced traveller information Access to personalised mobility information	Indirect promotion of use of mobile phones while driving Wider use may require significant energy Natural resources for manufacturing Social exclusion for technologically deprived Questions on cost of technology by all potential users
Horizon 2020 Priorities	Better data about emissions *etc* Contributes to a better, greener traffic management Openings for suppliers of equipment and services (*c.f.* SafeTRIP www.safetrip.eu) More scope for research on traffic assignment algorithms	Intrusion into personal data Some residents will lose from the reshuffling of traffic Monopolies could emerge and SMEs could end up excluded Focus only on applications and not on theory

Table 3.1: Summary of benefits and challenges of increased mobile communications

3.2. Increased Data Availability

The research theme on increased data availability is expected to deliver fundamental contributions to other research themes which will require high-quality data for monitoring and modelling complex phenomena of traffic flow, energy consumption and environmental impact. This research will have an indirect role for the objectives identified for NEARCTIS and the priorities of Horizon 2020; nevertheless the impact of research outputs will reinforce the effectiveness of data management in many fields of application with a particular focus on ICT-based services.

The issues that require research in this theme include data quality, data fusion and data processing of multiple and heterogeneous data sources. The research addressing increased data availability will facilitate the development and employment of effective tools for the assessment of data quality, advanced algorithms for a better data integration and adequate statistical methods. The outcome will be robust, well understood data to support research in other themes.

A better description of data models and metadata will be supporting new capabilities in the combination of different sources of data which will enable smart management of traffic according to or in response to environmental conditions, weather forecast and air quality. Increasing the amount of data augments the risk of mixing data with different levels of quality. The high redundancy will not replace the need for an adequate concept of quality data management. In summary, this research theme will better integrate the segments of data management, data processing and data fusion.

3.2.1. Objectives identified for NEARCTIS

Safety Potential improvements in road safety arise from a large number of measures to which co-operative ICT can make a key contribution in passive or active safety. The development of safety-related applications will depend on the timely availability of reliable data. Users will trust in warnings, in speed limit information or in traffic regulations only if the information is correct, and is transmitted in a due time and to the exact location.

The benefit of this research theme is the availability of a quality concept and tools for the assessment of data quality in several ITS services. This will enhance new developments in more robust applications and will improve the synergy with other stakeholders involved in road safety (*e.g.* insurance companies). All co-operative safety applications will be enabled by using reliable data for the deployment of safe infrastructures and services (*e.g.* safe intersections, safe speed advice). The deployment of safety-critical applications will only be possible when using certified data. This research will contribute to the process of certification and maintenance of reliable and verified data.

Environmental Impact Many approaches have been proposed for reducing the environmental impacts of road transport. Co-Operative traffic management is one of the promising actions for reducing fuel consumption, improving air quality and avoiding traffic congestion in specific areas. The improvement of environmental conditions results from complex processes with the interaction of many sub-systems like drivers, cars, infrastructures, built and natural environment. In this context, data management is a real challenge while combining different sources of information with challenging exchange of data.

The benefit of this research theme is that it will improve management of data flow and interoperability of road and traffic data within the context of an environmental data warehouse. Innovative metadata models will be available for environmental monitoring in interaction with traffic flow modelling. Tools for the aggregation of data and interaction with modelling are needed to support measures reducing environmental impacts. Therefore, these tools will support the measures for reducing the environmental impact, which must be proportionate according to local, regional or national specificities. Data and models being equally important, this research will contribute to a better integration of environmental modelling and monitoring, knowing which model is more appropriate for a specific application.

This research area is broad and on-going activities are already focusing on the generic topic of data interoperability. Therefore it will be necessary to adopt some of the existing specifications and models (*e.g.* the INSPIRE directive, http://inspire.jrc.ec.europa.eu/), and to develop new concepts on this basis.

Efficiency of the Transport System One of the key aspects of the efficiency of the transport system is the optimal use of different modes according to economic and environmental criteria. For travellers, a smooth and continuous mobility is expected and has a deep impact on the perception of the system performance. Each transport segment has already implemented advanced management tools, mainly based on relational database and geographic information systems. However the efficiency is mainly optimised for a specific mode of transport, and accessing and optimising with respect to multimodal databases is still challenging.

This research theme will improve the interoperability of information systems with the development of new standards in communication, traveller information and exchange of data. One of the main advantages will result from the innovative concept of communication/exchange of data between transport systems and user community. The deployment of solutions independently of transport mode will increase the potential of data exchange. Therefore, multimodal route choice will be possible without break (gaps) between transport modes. This research will support continuity of service across the trans-European transport network.

Traveller and System User Experience Traveller and transport users feel more comfortable when they receive reliable information on the status of the transport system. In case of incidents, it is necessary to send appropriate and timely information to users who need to change their plans or to search for alternative mode of transport.

This research theme will provide solutions for extensive integration of traffic and traveller information. It i important to ensure that different information channels do not provide contradictory messages to users. Quality check tools will help operators in the formulation of reliable and adequate messages according to multiple sources of information. This research will support reliability which is highly desirable for the deployment of robust ITS services accepted by the user community. A better knowledge of data sources, especially with the integration of destination information, will allow creating much more accurate and adequate information for the users.

Societal Impacts, Costs and Equity. The wide dissemination of mobile communication and information is a reality, and privacy issues are becoming more and more critical (*e.g.* see legal action against Carrier IQ). Users have no trust in non-transparent and intrusive services. There is always a risk of non explicit use of personal information (*e.g.* location-based service) .

This research theme will promote open solutions and tools for using and accessing data according to rules and best practices in order to guarantee privacy. The result of this research will promote the equity of access to ITS services based on appropriate data management which takes into account existing rules, policies and legal aspects. Robust tools for data quality management will be an advantage for service providers who can optimise costs of services with more reliable information.

3.2.2. Horizon 2020 Priorities

Societal challenges One of the goals under the umbrella of "societal challenges" results in promoting interdisciplinary co-operation involving generic technologies and sciences, and interactions with the relevant policies.

This context is particularly favourable for the development of novel research on data quality management and data fusion. Semantic and conceptual data modelling are fundamental pillars for interdisciplinary research and development. The use of model-driven approaches (object-oriented) is a key aspect for promoting common language between disciplines. This will improve the perception of some phenomena in our society across different fields including technology, social sciences and humanities.

Industrial Leadership Multiple sources of data, contradictory information and lack of exchange of data are reducing the competitiveness of SMEs and the deployment of new services. Fast and open access to data is a fundamental support to innovation which requires an efficient data warehouse with advanced models. This will enable the sharing of information among ser-

Data Availability	Benefits	Challenges
NEARCTIS objectives	More and better data available for analysis and model development Better understanding of data quality Range of appropriate data available	Privacy concerns on inappropriate use of personal data Requires management and processing resources
Horizon 2020 Priorities	Encouraging inter-disciplinary research and cooperation Opportunities to develop new services	Ensuring data is easily accessible *via* data repositories Avoiding data hoarding Ensuring effective use of the data

Table 3.2: Summary of the benefits and challenges of data availability

vices providers, public and private organisations. This research will promote open access to data and models and can contribute to the development of new business models.

SMEs will be actively involved across the Horizon 2020 programme and will also improve the synergy between research partners. Such research themes as data modelling and data quality management will bring to SMEs a valuable basis for the development of innovative services and applications.

Excellent Science Strong focus on innovation is the main objective developed in the Horizon 2020. This leads to the reinforcement of scientific excellence and creativity. A better integration of education, research and innovation is certainly the most encouraging way for young researchers and for future entrepreneurs.

Access to information and also to high-quality databases are necessary conditions for improving the integration between science and education. The development of joint structures (science or technology hubs) between universitIES, start-up companies and research centres has proved that sharing resources (*e.g.* database) is a route to success. It improves technology transfer and ”connects” faster emerging developments with the market.

This research theme will facilitate interoperability which will ensure that systems and business processes will have the capacity to exchange data and to share information in a proper and efficient manner.

3.2.3. Summary

This theme of research will be supporting fully integrated topics from fundamental concepts to the implementation of models. Thinking about interoperability from the early stage of a new development is a key aspect for a better integration of complex models, especially in the environment. The main benefits of this research theme are: the availability of innovative data models, metadata and mechanisms for the exchange of data; the development of tools for the assessment of data quality which will allow the deployment of liability or safety-critical applications; a better interoperability of applications with a particular focus on co-operative multimodal management; the development of smart data-warehouse gathering multiple sources of data in a consistent and effective manner.

This research theme has also some identified drawbacks: the indirect costs induced by the increased time necessary for the management and processing of huge amount of data; the difficulty of defining the barrier between public data and private data which can have a deep impact on privacy issues; data models becoming increasingly complicated, which will hinder access to data for all kind of users and thus may lead to risk of a monopoly by major service providers.

3.3. Improved Modelling at all Scales

Models are at the heart of any planning and management task. Despite some successes in recent years, models still lack a sufficient degree of realism, and this is true on all scales, from microscopic driver behaviour when following another vehicle, to route choice behaviour that among other things strongly determines the congestion patterns in a transport network.

Therefore, an important topic of a future research programme in traffic management is to improve upon the modelling capabilities of the traffic models. It is important to understand the effect that intelligent transport system measures, such as driver assistant systems, and communication and co-operation between vehicles and infrastructure will have on traffic behaviour and conditions, including but not limited to congestion patterns, and their contributions to traffic control objectives such as minimising travel time, fuel use, noise, and emissions.

Within D14, the research areas:

1. Real-Time Estimation of Traffic Conditions,
2. Improved Estimation of Travel Time and Other Performance Measures,
3. Dynamic Modelling of Travel Behaviour, and
4. Microscopic traffic flow models for safety issues

have been identified as the most important ones related to improved modelling at all scales. In the following, these research areas are evaluated to see if their possible contributions correspond to the objectives defined by the NEARCTIS Network of Excellence and in the Horizon 2020 of the EU.

3.3.1. Objectives identified for NEARCTIS

Safety Improved modelling has both direct and indirect effects on traffic safety. Knowing the drivers and travellers much better in the sense of a sensible model can help to understand safety issues in greater detail even before they became manifest in the form of accidents or critical situations. In this manner, areas can be made safer immediately once an improved model clearly points towards a safety issue in this area. Furthermore, such a model can also indicate what counter-measures should be used.

The indirect effect works through the provision of information,*i.e.* by communicating with road-users. Knowing the real-time traffic conditions precisely makes it possible to issue warnings especially to those travellers, who are about to cross a region with critical, especially with safety-critical conditions. Knowing how the travellers choose their best means to travel from origin to destination can also help to provide them with the needed information to make their travel safer.

Environmental Impact Several mechanisms can contribute to reducing the adverse environmental impacts of the transport system. Having more detailed emission and air quality models is one; however, in addition, also better models that more accurately describe driver behaviour help to better estimate the emissions produced. Having estimated the flow of vehicles on each length of road, there are essentially three different further modelling steps. The driver modelling is needed in order to establish the correct acceleration and speed of the vehicles, and the corresponding engine speed. From this, the emissions produced by the vehicle can be computed, and this part of the task seems so far the one that is best understood. Finally, the emissions produced will be transported and transformed, and this again is not an easy task since the detailed geometries in the cities are very complicated and many chemical reactions are involved. So, models can be used to compute the emissions produced by the transport system at all scales and resulting air quality, from regional down to local scale. They are, of course, already used for this purpose right now, but with limited and often unknown precision.

Given the limited number of emission measurement devices (a typical German city usually has only a few of those emission measurement stations but greater numbers of pervasive sensors are installed in some British cities), effective modelling using mobile data gathering (*c.f.*3.2.) can be used to establish emission and air quality for those the many place where there is no explicit emission measurement. This, then, in turn helps to design possible countermeasures to lead to a transport system that minimises environmental impacts as far as possible.

Finally, the planning processes may benefit from improved modelling. Currently, environmental impacts are rarely taken into account in the design of new infrastructure, and if they are, they are only considered a later stage, *e.g.* designs with lower environmental impact are preferred. This process can be reversed: optimising first in order to minimise environmental impacts, and only second in order to take into account the additional objectives (resources, geometry, and travel time). Such an optimisation sequence can change the whole planning process strongly. Ultimately, planning processes will be developed that consider all objectives simultaneously, each weighted according to its importance. This approach is desirable in that it will lead to improved performance and will be free from arbitrary issues such as sequence of optimisation. However, technical and computational issues will need to be addressed in the process of development.

Efficiency of the Transport System Models are already used extensively to estimate the effects of new and existing control and management measures. However, when it comes to the effects that communication might have on the overall performance of the transport system, we still face a modelling gap. By several simulation experiments, it has been demonstrated that especially the communication between vehicles and between vehicles and infrastructure can help to improve the overall efficiency of the transport system. However, most of these simulation experiments only display an outcome that stems from somewhat artificial conditions. It is also necessary to avoid side effects such as Braess-like effects (*e.g.*the assignment of traffic towards attractive routes though environmentally sensitive areas), and more generally to assess the reactions to information and communication in the transport system. Having better models will help to estimate the benefits of such a co-operative traffic management in a more reliable manner. Given this, a better estimate of the benefits of a certain new policy may lead to additional improvements. Consider, for instance, the coordination between traffic lights. By making them much more traffic responsive, with data that are difficult to obtain by traditional means (*e.g.* travel times, delay times, vehicles may even inform the controller about their current emission or engine or battery state, a useful feature for use of electrical vehicles), much more flexible and possibly more efficient control policies may be designed - itself a very interesting and fertile field of research.

Traveller and System User Experience Most of the effects of improved modelling on the user experience are indirect. Better models mean not only knowing better the current state of the system (real-time estimation) but also better estimation of the short-term future traffic condition. Since this information can be shared in a co-operative transport system with the users, they can use this information either to change and adapt their travel plans, or at least adjust their expectations. Realistic expectations have been shown to be an important added value of information.

Better modelling can also help anticipate the most likely reactions of the travellers and users, and this will help to design policies that have a better level of acceptance as well as being more effective. This in turn improves the reliability of the measures, which again improves the acceptance by the users at least in part - as long as they are not too adversely affected by the improved control policy.

Societal Impacts, Costs and Equity. Improving the safety and reliability of the transport system leads to positive societal impacts, as long as careful consideration is given to environmentally sensitive areas. Of course, there exists a kind of critical threshold when too much traffic gets diverted to too few main routes, when it becomes more attractive to move through areas that should be protected from extra traffic. Again, how to stay well below such a threshold is a feature that can be estimated with improved modelling. However, other measures could be implemented to support the proper control of the traffic flow, such as for example a toll that is based not on the time of the day, but on the ”protectedness” of the area under consideration. Once more, this might only be achievable with the additional communication means that comes with a co-operative transport system. Furthermore, the estimates delivered by the improved modelling also act as indicators to help to achieve a sustainable urban environment. Models can also help to assess and improve the equity of various aspects of the transport system.

3.3.2. Horizon 2020 Priorities

Societal challenges The transport-related societal challenges in Horizon 2020 have been stated as the goal to have a smarter, greener, and more integrated transport system that supports a sustainable development within Europe. This fits well with the NEARCTIS’ objectives of safety, efficiency and environmental impacts.

Industrial Leadership This is affected only indirectly by progress in the research areas discussed here. Improved efficiency of transportation will affect the efficiency of the economic system as a whole. Obviously, having better models can help *e.g.* the traffic industry to design better control devices, better planning and management tools and better traffic management centres. It may also help to provide users with better and more tailored information, which is to be provided by specialised companies. All this could improve the know-how, the standing and well-being of European companies on the world market.

It is to be expected that some or all of the improved models will be incorporated into products sold by European SMEs or will be used by consultancies. In addition, those SMEs might provide researchers with their own views of what is important to them and what not. This point is sometimes give inadequate attention by researchers and therefore needs to be emphasised. In addition to that most research organisations in Europe have already established quite efficient means to help create spin-offs in the form of SMEs that will transfer existing research results into even more exciting products.

Improved Modelling	Benefits	Challenges
NEARCTIS objectives	Improved understanding of traffic behaviour More reliable estimates of journey times Better models for management tools Better estimates of emissions	Making effective use of available data. Ensuring easy transfer of configurations, data and results between model Too much reliance on model predictions. Inappropriate responses to model predictions
Horizon 2020 Priorities	Improved control of emissions Integration of models into products of SMEs Enhanced scientific leadership in traffic modelling, management and control	

Table 3.3: Summary of the benefits and challenges of improved modelling

Excellent Science Improved modelling, for all the four research areas described above, will obviously have a strong impact on Europe's science base. All four areas contain tremendous scientific challenges that can only be mastered when a lot of different approaches play together: better models, better numerical and computational concepts, and of course, since we are dealing with really large systems, performing distributed computing in the cloud or on large parallel machines. Succeeding in this endeavour will clearly prove Europe's excellence in performing applied as well as fundamental research. In addition, it will have an element of reinforcement in it, since it will draw other researchers world-wide to join, to co-operate with and to emulate European research groups.

3.3.3. Summary

Putting everything together, there is a large degree of coherence between the research topics and both the NEARCTIS objectives and the Horizon 2020 priorities. Therefore, it is expected that the research works identified in D14 will bring positive impacts regarding not only the transport and environmental issues but also the societal, innovation and competitiveness concerns.

3.4. The Need for Communication Between Autonomous Systems

The concept of communication between autonomous systems is fundamental to the idea of co-operative transport systems, both at the detailed level of individual (autonomous) vehicles communicating with each other and at the higher level of separate monitoring and communications systems exchanging information for the greater good. It is therefore initially surprising that the harmonised research programme contains only one research area (Fleet Management) in its section on ’The need for communications between autonomous systems’.

However it is the fundamental nature of the issues of autonomous systems that leads to this situation. This research theme can primarily be an enabler for future more applied themes, leading to communication and co-operation actually being spread throughout the harmonised research programme. For example, as well as the research in *D14:3.4.1 Co-Operative Strategies for Fleet Management*, communication between autonomous systems is also found in:

D14:3.1.1 Data Capture — ’Effective management of the transport system requires up to date information on both the current state of traffic on the network and of traffic management measures in operation.’ Such knowledge can only be achieved if the separate monitoring and control systems communicate.

D14:3.1.2 Improved Traveller Information, D14:3.6.1 Incident Management — To maximise the potential for innovation in information delivery systems, there needs to be the potential for information delivery mechanisms that are separate from the monitoring and management systems.

D14:3.2.2 Data Collection and Fusion, D14:3.3.1 Real-Time Estimation — If diverse sources of data are to be combined, then the systems producing that data must communicate.

D14:3.5.2 Multi-scale Traffic Control — communication between driver intention and control systems is necessary to achieve the highest resolution of control decisions.

D14:3.6.5 Responsive and Adaptive Optimisation — Communication between control and monitoring systems is necessary to enable consequences of control decisions to be accurately assessed.

D14:3.6.7 Differential Road Pricing — Communication between monitoring systems, toll setting systems and traveller information systems is necessary for appropriate toll levels to be determined and communicated to travellers.

Despite the initial impression therefore, the harmonised research programme actually contains many examples of communications between autonomous systems, based on either Vehicle-to-Infrastructure or Infrastructure-to-Vehicle, or in some cases Infrastructure-to-Infrastructure communication. However, it contains relatively few recommendations for research which utilises the potential for Vehicle-to-Vehicle interaction, although this may in part be because much of this form of communication is already being extensively researched elsewhere.

Together these research areas illustrate the core nature of communication between autonomous systems to the delivery of the expected benefits of the harmonised research programme. This chapter therefore analyses both the direct and indirect benefits likely to be enabled or obtained through such communication in relation to the core objectives of the NEARCTIS project and Horizon 2020, as well as highlighting some of the potential undesirable consequences that may occur without sufficient research focus.

3.4.1. Objectives identified for NEARCTIS

Safety While much of this research focus is related to Vehicle to Vehicle communication, the harmonised research programme makes a specific focus on improved data collection and fusion for the better understanding of network conditions and on improved incident management based on integration of monitoring and information systems with control systems. This improved ability to detect more rapidly and react in a more coordinated way to evolving incidents could be expected to achieve substantial safety benefits both directly in terms of reduced collisions through improved vehicle safety systems (*e.g.* collision avoidance systems) and also indirectly through improved rerouting of vehicles away from traffic conditions known to give rise to greater risk of incidents (*e.g.* stop-go traffic queues or high speed - high density flows).

Environmental Impact Although not explicitly identified as a key focus, the research areas in differential road pricing and responsive optimisation could use communications between autonomous monitoring and control systems to optimise traffic against environmental impact objectives as well as economic objectives. If this approach was taken optimisation of traffic patterns against environmental criteria would be enabled alongside more traditional time/cost optimisations. It is recognised however that key to realising such benefits will be the creation of a comprehensive real time picture of traffic and environmental conditions (*i.e.* the level of data communication with environmental monitoring systems must match the level of communications with traffic monitoring systems) or else the risk occurs that the optimisation will simply relocate the current environmental impacts to alternative locations/times rather than achieve the desired reductions.

Efficiency of the Transport System This is a key objective of many of the research areas in the harmonised research programme that include communication between autonomous systems (*e.g.* Multi-scale traffic control, incident management and fleet management) and as such is anticipated to provide substantial advances in efficiency both directly for the fleets involved and indirectly for the wider traffic flows. The efficiency of the transport system is expected to increase through the introduction of new technologies, the enhancement of current monitoring and the improvement in journey time measurement. The communication between autonomous systems is meant to facilitate the operation of new technologies and management of data. One of the dangers related to the different autonomous systems is the possibility of information overload and special attention should be given to data consistency.

Traveller and System User Experience Although the direct impacts of the autonomous system communications research on the experience of individual travellers will be limited, the better understandings and transport network management that results could be expected to reduce delays and improve the quality and accuracy of traveller information. However, a major risk here is the existence of unstable feedback within traffic state — traveller information system loops. The understanding of the current network state increases in temporal and spatial resolution through greater communication between different monitoring systems. If such information is going to be disseminated more rapidly and more widely through better communication with real time information systems, then the risk that arises is that increasingly large proportions of travellers will choose to react spontaneously to new information leading to sudden swings in traffic state. Overall, the aim will be that traveller experience will improve due to higher reliability and speed of dissemination of information due to the better communication.

Societal Impacts, Costs and Equity. With the possible exception of the differential road pricing research area, this is not a key objective of the proposed autonomous systems communication research areas, but some indirect benefits will arise through (for example) improved reliability and safety, and reduced environmental impacts. There are also indirect drawbacks falling upon users and residents (*e.g.* noise and environmental impacts). It needs to be assured that both advantages and disadvantages will be distributed among individuals in a fair and equitable way.

3.4.2. Horizon 2020 Priorities

Societal challenges With the possible exception of the differential road pricing research area, this is not a key objective of the proposed autonomous systems communication research areas, but some indirect benefits will arise through (for example) improved reliability and safety, and reduced environmental impacts. One additional societal challenge however is to reassure the public that any sensitive data remain strictly confidential and are used only to ameliorate the transport system's efficiency without revealing information about individuals.

Industrial Leadership Perhaps the key issue of concern here for delivering the potential impact of research into autonomous systems communication across the three industrial leadership objectives of Horizon 2020 is not about the research areas themselves, but the level of openness with which the resultant autonomous systems operate. The real benefits for competitiveness, will only be realised if the interfaces with which the autonomous systems communicate are publicly available, reducing the barriers to entry into traffic monitoring and information provision markets by enabling additional systems to be created (*e.g.* systems that address key monitoring or information needs) which simply communicate with existing systems. The competitiveness may lead to improved services provided through harmonised communication between various autonomous systems, but there is a real risk that although the systems themselves are

Autonomous Systems	Benefits	Challenges
NEARCTIS objectives	Improved incident detection and response Improved routing advice especially after incidents	Over-reliance on communications leads to fragile systems Excessive communication leads to bandwidth and latency problems
Horizon 2020 Priorities	Central organising concept contributing to a safer, greener more integrated transport system Open system specifications encourages innovation Encouragement of modal choice and switching	Concerns over confidentiality and use of personal data

Table 3.4: Summary of the benefits and challenges of communication between autonomous systems

autonomous, unless the communication interfaces are open, the potential for creation of added value systems will be greatly reduced.

Small and medium sized enterprises may find direct and indirect opportunities to capture a significant place in the market through this research theme. Directly there could be many services to be provided by an SME or instances of management of an autonomous system that could be outsourced to an SME. There could also be introduction of innovative autonomous systems from scratch to complement existing systems beneficially in terms of gaps in existing data collection. Indirectly, SMEs may also attempt to improve the transport system in various ways, by adding value to the better understanding enabled by improved co-operation of autonomous systems.

Excellent Science The communication between autonomous systems may indirectly improve Europe's science base in the field of transport, as it will identify potential needs and questions that need to be tackled by the European research community. Some of these needs and questions are related specifically to transport, whereas others (*e.g.* data fusion, information overload) are more generic but are ones where transport will provide substantial and economically important case studies.

3.4.3. Summary

This chapter analyses both the direct and indirect benefits likely to be enabled/obtained through communication between autonomous systems in relation to the core objectives of the NEARCTIS project and HORIZON 2020. For this research theme, the most relevant NEARCTIS objectives are the efficiency of transport system, safety and traveller experience. Particularly for the safety objective, through the improved co-operation, the capability of incident detection and response will be significantly improved and therefore benefit safety directly.

For the Horizon 2020 priorities, societal challenges and industrial competitiveness are the most promising areas associated with the various autonomous systems research areas, but it is recognised that openness within the communications interfaces will be a key determinant of success. While this research theme is predominantly an enabler for downstream applications, its success facilitates many potential applications leading to benefits across all the NEARCTIS objectives and the identified Horizon 2020 priorities.

3.5. Understanding Interactions at Various Levels

In the research framework described in D14 mechanisms of co-operation at different levels leading to coherent and desirable behaviour have been discussed. In D14 the following research areas have been distinguished: intelligent vehicles, multi-scale traffic control and understanding interactions. However, as the research areas identified in D14 do not seem to cover the complete research field, which should be covered in the assessment presented in this chapter, it is useful to re-organise the research topics according to the interaction between different levels of co-operative traffic management (*e.g.* interaction between centralised traffic management and intelligent vehicles). This results in the following research areas:

1. Interaction between autonomous intelligent vehicles and emergent self-organised patterns
2. Multi-scale traffic management, by which is meant hierarchical traffic control systems that aim at solving problems locally if possible, and in more integrated ways (*e.g.* at arterial level or network level) if required.
3. Interaction between road-side traffic management and in-car systems, by which is meant integration of traditional traffic management systems (*e.g.* ramp-metering, VMS, traffic management and control systems), and in-car information and data collection.

These three aspects show an increased exploitation and integration of traditional traffic management and intelligent vehicles. The three levels reflect increasing levels of coordination (from self-organisation to stronger coordination at the system level). This chapter analyses the impacts of the interactions at various levels with respect to the NEARCTIS objectives and the Horizon 2020 priorities.

3.5.1. Objectives identified for NEARCTIS

Safety At the individual level intelligent vehicles may directly lead to safer driving by guaranteeing lateral position management within lanes and speed-dependent minimal spacing from the preceding vehicle. Intelligent systems may reduce the likelihood of inevitable human error and thereby reduce the likelihood of collisions (thus increasing safety). In theory, communication (interaction) between vehicles can make the traffic conditions even safer as vehicles may send warnings of downstream congestion (decreases in speed). However, if vehicles anticipate future conditions on the basis of the systems information, changing their headways and their speeds, the dependence on the systems generally increases. If a collision does occur, the intelligent systems will be able to communicate relevant information that can be used both to activate emergency services earlier and more accurately and to optimise traffic management.

Local traffic controllers generally improve local conditions (usually throughput related). The multi-scale approach can take into account the functional ordering of the roads in the network (describing the functions of the different roads), and as such explicitly consider so-called protected roads, which are not to be used for regional traffic management for safety or environmental reasons (or only under very restrictive conditions). Further integration with in-car systems (travel support, in-car routing information and advice) should improved the effectiveness of use of these roads (including that of protected roads) through direct communication to the road users.

Another possible effect of multi-scale traffic management is an improvement in throughput, traffic calming and homogenised flow conditions, which often also results in a reduction in the incidence of congestion and (moving) shockwaves. As these waves are known to be the cause of incidents, there is an indirect (positive) effect on safety.

Environmental Impacts Intelligent vehicles are increasingly equipped with new technologies for adaptive cruise control (ACC), dynamic route guidance and hazard warning systems. These technologies may reduce fuel consumption and emissions by providing support at the operational level (ACC) as well as at the tactical level, when choosing optimal routes avoiding congestion. Often, intelligent vehicles are also equipped with hybrid and electrically powered units, having a direct impact on the environment. However, without explicit consideration of areas, which are preferably to be avoided (and hot-spots for that matter), rat-running may occur and increases in traffic flow where it is not desired from a environmental perspective may occur.

As for safety, a multi-scale controller functioning according to regional policy can explicitly take into account the necessary limitation in the use of specific roads in order to meet environmental norms (*via* the protected roads concept).

Increased co-operation between traffic control systems makes it possible to distribute the inconvenience from a local bottleneck over a larger area. Local effects of extra noise and emissions due to congestion may therefore be reduced, but be increased slightly at other locations. Also, personal travel support systems could take into account the functions of the different roads, and as such discourage drivers from using roads that are protected for environmental or safety reasons.

As for safety, indirect environmental benefits may result as a consequence of improved efficiency of the traffic system as a whole, through which high accelerations (which have detrimental effects on both noise and emissions) are prevented.

Efficiency of the Transport System Different characteristics of hybrid and electrically powered vehicles may change the road capacity, as well as traffic flow stability, and thus the efficiency of the transport system. Furthermore, it is known that choice behaviour stemming from individual route information and advice will not yield a situation which is optimal from a system's perspective..

Increased co-operation between traffic control systems increases the control space and thus the opportunities to solve congestion in an area. A good example of this is coordinated ramp-metering, where the additional storage space provided by the upstream ramp-meters is used to enable longer and thus more efficient metering. This will have a positive effect on the efficiency of the transport system. This positive effect does not only relate to travel times, but also to travel time variability, as the predictability of travel times will increase and travel times are known to vary more in situations near capacity.

Co-operation between the traffic management system for regional traffic management (such as currently used in the Amsterdam region, using traffic management scenarios to determine which combination of measures should to be deployed under specific conditions) and in-car systems should lead to additional efficacy of the traffic management, information and control. First of all, the in-car system provides valuable data to improve traffic management as well as to advance data collection in general as the in-car system can supply a wide range of transport data. Second, traffic management information and guidance will be sent to individual vehicles (*e.g.* delay times due to ramp-metering, or changed signal control settings) yielding better information and allowing the road-users to change their route if they wish.

Traveller and system user experience Experience with as well as the maturing of intelligent systems will improve user acceptance, and thus increase their penetration over the coming years. User experience and acceptance will also affect the choice and further development of functionalities in the intelligent vehicles.

Interaction between the centralised traffic management system and in-car (information) systems should improve information provision to road users substantially, not only providing actual and accurate information on traffic conditions, but also on the status of the traffic management measures. Moreover, this form of interaction should lead to consistency in information provided *via* different channels (roadside, in-car *etc*) leading to improved user-acceptance.

Higher levels of coordination with the capability to impose choices upon drivers may lower public acceptance, due to their reduced freedom of choice to choose any route or departure time. Here, enforcement would come into play, to ensure that traffic management measures were indeed followed.

Societal impacts, costs and equity Improved throughput, reliability, safety and environment have obvious positive societal impacts. The costs of setting up the interactions required to bring these about stem from: 1) research and development; 2) technically enabling current systems for interaction with a supervisor, and with in-car systems and 3) operational cost of running and maintaining these systems. Some of these costs will fall on the road authorities and some on private companies (service providers, in-car hardware manufacturers *etc*) in the first instance; how they are passed on to citizens and customers will be another matter. Public takeup is an immediate issue only for the use of in-vehicle information, of which the cost will be the most important factor. This may result in a situation where only some of the travellers are actively using the provided information, which may lead to some form of inequity.

Another aspect of equity relates to which road users will suffer delays, depending on the choice made by the traffic management system where to distribute which traffic. Vehicles in initially unhindered areas will this way encounter delays which they would not have had if no traffic management had been performed.

3.5.2. Horizon 2020 Priorities

Societal Challenges For Horizon 2020, the main challenge is a smart, green and integrated transport system. This complies with the fact that sustainable development will be an overarching objective of Horizon 2020.

Societal challenges relevant for this research area are efficient transport, less congestion and more safety, while at the same time reducing the impact on the environment and reducing the dependency on fossil fuels. In the previous sections, the benefits of understanding interactions at various levels in relation to the societal challenges have already been indicated: it was argued that higher levels of interaction and increased co-operation and integration will lead to a more efficient, greener transport system. In this respect, the transport challenge, smart, green and integrated is addressed.

Not only the pure reduction of congestion, but also its distribution over a larger area can in suitable circumstances be made to result in benefits for a larger part of the population as the negative effects for both traffic participants and people living in the neighbourhood are distributed so that the gainers outnumber the losers.

A more practical issue is the fact that people need to be made aware of the results of research on intelligent vehicles and to a larger extent on stand-alone multi-scale traffic management systems as well as in interaction with in-car systems, *e.g.* by performing pilot studies in order to facilitate the roll-out of these systems in practice. Only this way, will society truly benefit from this research.

Industrial Leadership Competitiveness can be increased in a number of ways. First of all, the automotive industry and its direct suppliers will be affected by the improvements in functionalities in in-car systems and communication technologies necessary for the communication between the vehicles and roadside equipment as well as by the products that can be retrofitted. Secondly, Europe is characterised by a large number of areas, which may benefit from Multi Scale Traffic Management (MSTM). Pilot studies in one or more of these areas to show the benefits of MSTM will increase not only the scientific knowledge and insight into these management systems, but also the practical, technological and policy related knowledge on how such systems should be developed. In particular, ICT companies and system developers , service providers , and the traffic industry will benefit from the innovations achieved here.

Both multi scale traffic management and further developments in intelligent vehicles require many participating parties. In particular the co-operation between these parties, each with their own point of view and complementary skills, will stimulate progress and scientific developments. In addition, entrepreneurial activities of universities may result in spinoff companies, typically SMEs, which can market the innovations.

Excellent Science To develop multi scale traffic management, intelligent vehicles as well as interaction between intelligent vehicles and traffic management a lot of knowledge still need to be developed. This knowledge includes both fundamental scientific knowledge related to the development of traffic management algorithms and practical or applied knowledge for the field studies and the functionalities of the intelligent vehicles. As the task is large, it should not only bring together the top of the European researchers, but it also needs new researchers to accept this challenge, which will increase the scientific knowledge level in Europe, thus contributing to raising the level of excellence in Europe's science base and ensuring a steady stream of world-class research.

A possible threat is the potential knowledge leak, where researchers from outside Europe are educated at European institutes and work on European funded projects, while after receiving their doctorate returning to their homeland taking valuable knowledge with them, with which they can create competitive research institutes and competing companies.

Understanding Interactions	Benefits	Challenges
NEARCTIS objectives	Vehicle to vehicle communication to improve safety Support for driving response to traffic conditions Traffic controllers responsive to traffic conditions elsewhere in the wider network	Avoiding disruptive feedback effects Need for public take up of communicating vehicles
Horizon 2020 Priorities	Reduced congestion and smoother traffic flow Opportunities for SMEs to supply equipment and services	

Table 3.5: Summary of the benefits and challenges of understanding interactions at various levels

3.5.3. Summary

The research theme on understanding interaction at various levels is characterised by research with three different levels of interaction between autonomous intelligent vehicles and (multi-scale) traffic management systems. Improvements are expected in more efficient driving leading to higher capacities of individual roads, distribution of congestion over larger areas thus reducing not only delays, travel time variability, fuel consumption and emissions, but also distributing nuisance caused by the traffic system as a whole more equally and higher safety levels. Drawbacks are found in the equity of the system: intelligent vehicles come at a price that is not affordable for everybody, and distributing traffic over a network implies making choices about which drivers will experience how much delay. In addition, intelligent vehicles and other systems supporting driving behaviour require a large change in driver attitude and may reduce driver's freedom to make choices. However, the benefits, not only for the traffic system as a whole but also for individual drivers seem likely to outweigh these drawbacks. With respect to the Horizon 2020 priorities, the various research themes appear to have in general a positive effect.

3.6. Achieving effective large-scale transport systems and their efficient usage

This theme contains many of the final core areas of Traffic Management, including incident management, and motorway and urban traffic control. These areas address the final decision-making on actions and controls to be actually applied in real time. This decision-making relies heavily on equally significant developments and contributions that are addressed in other research themes. For example, mobile communications, data availability, or advanced modelling are substantial prerequisites for the successful development of advanced traffic control strategies and systems addressed within the theme. Advanced real-time traffic management systems incorporate a whole chain of subsystems and sub-areas that need to interact and co-operate in a harmonious way towards the achievement of the targeted objectives and evaluation criteria, and this theme is concerned with one specific sub-area.

3.6.1. Objectives identified for NEARCTIS

Safety Traffic safety is a significant, in fact omnipresent, objective or concern of any traffic management plan or action. There is a continuing need to reduce the number of accidents, injuries and fatalities incurred by road vehicle traffic. The present research theme contributes to this significant objective directly and indirectly. A direct contribution to enhanced traffic safety is achieved by traffic management measures that focus explicitly on safety-relevant issues. A significant ingredient and expected outcome of advanced incident management is the faster detection of incidents and accidents and the more efficient dispatching of rescue teams, where necessary; Dynamic motorway signalling systems have almost completely eradicated head to tail collisions on the Dutch motorways. The integration of research addressing pedestrians and walkers as distinct entities, which will allow better design and improvement to management of urban multi-modal environments, is another example where pedestrian safety is a primary and direct focus. The investigation of factors contributing to accidents in rural roads, along with the analysis of detailed data on conflicts, close encounters and near-misses, is a direct contribution to safer traffic conditions on road infrastructure of this type.

On the other hand, traffic management actions aim at more efficient traffic operations on all kinds of road infrastructure, typically achieved by reducing the space-time extent of traffic congestion. Traffic congestion is closely related with moving shock waves (which imply a strong negative space-gradient for vehicle speeds), stop-and-go phenomena, and driver frustration and anxiety; all typically factors that are known to increase the risk of traffic accidents. Therefore, any congestion mitigation achievable is very likely also to deliver corresponding indirect improvements of traffic safety. Another relevant aspect is the need directly to reflect in traffic management decisions the estimated current risk level on strategic roads and motorways based on available and future measurements and information. This calls for the development of appropriate and reliable risk indicators that may be directly used in active traffic management systems as a trigger for the application of appropriate measures (*e.g.* speed limits) that are known to reduce the accident risk. Available research results in this direction need to be reinforced and extended to consider emerging information sources aiming at more reliable risk estimation. It should be noted that like most technological innovation, some envisaged advances in vehicle technologies, communications and co-operative traffic management may imply some risks for traffic safety and accident probability, *e.g.* due to driver confusion or distraction or over-reliance on technology. These risks should be addressed and minimised before and in the course of significant changes introduced in the expected driver functions.

Environmental Impact The environmental impact of vehicle traffic, including its impact on global warming, in terms of emissions, noise and more is a major concern of modern society. A direct benefit is achievable *via* appropriate quantitative modelling or measurements of the incurred environmental impact and its explicit consideration as an optimisation, control and evaluation criterion in planned or operational traffic management actions. Recent research work has been developing the corresponding necessary modelling and optimisation tools. Since the environmental impact is aggravated in cases of very low vehicle speeds, rapid speed changes and vehicle acceleration, an indirect environmental benefit may result as a consequence of the space-time decrease of road traffic congestion that is achievable *via* successful traffic management. Mode shift towards more environmentally friendly transport modes (*e.g.* walking, public transport), which may be triggered *via*, for example, more pedestrian-focussed traffic management or road pricing, has also the potential of reducing the environmental impact of modern transport systems.

Although the space-time extent of congestion is justifiably deemed to be correlated with the environmental impact of a road network and its traffic, a potential reduction of the prevailing extent of congestion may reveal some threats or countervailing effects that need to be carefully accounted for. These threats may be related to the very nature of the envisaged traffic management action, *e.g.* due to slowing down portions of the traffic flow (hence increasing their contribution to the environmental impact) to improve throughput for other traffic flow portions. In addition, a decrease in travel delays may be perceived as a motivation for travellers to modify their departure time or to shift to their car. For example, some recent studies indicated that improved signal coordination on arterial roads may, under certain circumstances, result in an increase in the environmental impact of the arterial traffic due to induced demand. Clearly, such statements should not be misunderstood as a discouragement from combating traffic congestion; but they underline the global character of the transport system that calls for consideration of inter-modal issues and appropriate trade-offs between different evaluation objectives.

Efficiency of the Transport System The daily congestion plaguing metropolitan road and motorway networks during the peak periods or in case of serious incidents is a major threat for the economic and social life in modern societies due to the incurred over-long delays and other detrimental impacts related to safety and the environment, as mentioned earlier. Most components of the theme address transport efficiency directly, for motorways, for urban road networks and for mixed networks within corridors. Advances in methodological (control, optimisation, integration and coordination) and technological (*e.g.* co-operative systems) areas and new applications (*e.g.* road pricing), if properly exploited, may lead to, in some cases very significant, improvements in terms of congestion mitigation and delay reduction. A more holistic approach, addressing different transport modes simultaneously, may deliver further and more balanced improvements for the overall metropolitan transport system. This is a major challenge that calls for substantial innovations that must be addressed at the administrative and political levels.

Traveller and System User Experience The traveller using the transport system has an interest in the proper scheduling of their activities. Important criteria are delays and journey time reliability. Before a journey, reliable and convenient multi-modal pre-trip information allows for proper and efficient mode and route choice; during the journey reliable information and recommendations, particularly in case of abnormal events allows for efficient real-time route and mode (*e.g.* park-and-ride) choice. In particular, journey time reliability is a specific user criterion that has been largely neglected in past developments, but seems quite crucial for the efficient planning of transportation of persons and goods. The traffic flow behaviour, particularly in saturated traffic conditions, is known to exhibit some chaotic characteristics, whereby small changes in demand or supply may lead to large changes in journey times. Feedback control is a well-known way to reduce chaotic characteristics, thereby improving the journey time reliability under normal peak-period traffic conditions. On the other hand, increased reliability under abnormal (*e.g.* incident induced) traffic conditions implies proper user information and fast implementation of control measures to mitigate the related delays.

Traffic management within this theme must address these traveller concerns sufficiently and improve user experience and choices. Appropriate user campaigns may be necessary in some cases to enable or increase user acceptance and proper utilisation of innovative systems. Enforcement, particularly for innovative or critical traffic management interventions, is another complementary aspect for better efficiency and more compliant user experience. Last not least, special user groups (*e.g.* elderly or handicapped people) may need special attention in the implementation of particular traffic management measures and actions. A potential threat in this context is the decentralisation of services (*e.g.* provision of information) by multiple providers with partly different scopes, interests and target groups. This trend, which is facilitated by available or emerging technologies and information sources, may, under certain circumstances, be contrary to the apparent need for more global, integrated and transparent approaches to the modern transportation requirements and may call for appropriate coordination and regulation actions to ensure synergy and harmonious co-operation of sub-systems.

Societal Impacts, Costs and Equity. The European Commission estimates the annual road congestion cost to be about €120 billion or 1% of the European Union's GDP. This is a cost suffered by private road users, companies and state institutions and does not include the environmental impact and traffic safety losses. Any achieved improvements *via* the research work under this theme will directly affect this cost and will contribute to more liveable conditions for metropolitan areas.

The theme has opportunities and challenges for equity. Firstly, the managed road infrastructure should provide for reasonable fairness in terms of journey times of different road user groups; more generally, traffic management should enable similar journey times for equal-distance trips (connecting any origins and destinations) within a sub-network, although without sufficient care this requirement may increase the total time spent by the whole driver population. Secondly, management measures maybe have different benefits to road users belonging to different income groups; *e.g.*road pricing, may in some cases be perceived as an advantage for road users with higher income, which may necessitate appropriate compensating measures such as the provision of high-quality public transport alternatives. Finally, equity should be considered to include not only travellers, but also those who are affected by traffic and transportation because of their living, working or walking locations. Another challenging issue is the share of the innovation cost. For example, in-vehicle systems, which enable the implementation of several co-operative functions at the traffic management level, will have to be paid for by their owners; such a scenario, however, implies special benefits for the owners as a motivation to purchase the systems in the first place. The situation is likely to become more complex with the involvement of vehicle fleets of various kinds, various commercial service providers *etc*. Although the corresponding challenges may be deemed more economic or even political than technical, they may have strong implications for the successful implementation of technological solutions, their targets and their implementation procedures.

3.6.2. Horizon 2020 Priorities

Societal challenges Despite the huge technological advances observed in many areas (*e.g.* communications: mobile phones, internet), the daily physical transport needs of modern society continue to suffer from excessive delays and environmental impact, as well as reduced traffic safety. This represents a major societal challenge and, in fact, the envisaged future research proposed in D14, and in particular within this theme, is aimed at addressing this major challenge. Despite the undeniable advances achieved in the recent past, sensible innovation is a prerequisite for more radical solutions, and this may call for paradigm changes, not only with respect to the employed traffic management methodologies and technologies, but also with respect to the research, development and deployment approaches and procedures. Research work on advanced traffic management can consider more explicitly the related practical and administrative concerns, but should also be given more opportunities to practically test, compare and deploy its outcomes. It should be emphasised, however, that attempted improvements in this vital area of modern human activity call for more than merely technical innovation and research funding; the organisational, administrative and political environment should facilitate the actual deployment of practicable innovative approaches, even at the expense of taking some reasonable risks, which can probably not be avoided completely. Having said that, any possible risks should not interfere with or jeopardise meeting other significant societal challenges, such as the global environmental concerns; careful trade-offs should facilitate proper advance in all societal domains of major interest.

Industrial Leadership An efficient transport system, enabled *via* promising, targeted and practicable research and development, is potentially beneficial for European competitiveness in at least two ways:

- First, a mitigation of the current traffic congestion problems on European roads will improve the efficiency and decrease the cost for a vast portion of domestic enterprises; in addition, it will render Europe a more attractive place for investment and businesses that rely, by their nature, on the efficiency of the road transport system.
- Second, the achieved know-how, if appropriately channelled to innovative commercial products and services, will mark an advantage for European enterprises involved in the traffic management sector. This will increase the international status and competitiveness of the industrial sector concerned and contribute to an increased deployment of European technology around the globe.

Increased competitiveness may also be perceived at the domestic level; regions investing in innovative and efficient traffic management solutions will experience competitive advantages which may trigger the faster deployment of innovation within Europe.

The required and identified innovative research work calls for co-operation of various actors with complementary skills, background, experience and capabilities. In particular, the mentioned need for practically relevant research results implies the involvement of actors with appropriate experience in planning, system integration, implementation and evaluation of transportation systems, such as SMEs of various types (system integrators, consultants, equipment providers and more). SMEs and research spin-offs may also act as carriers of innovative traffic management products and services resulting from the related European research.

Excellent Science European research has been traditionally leading world-wide in some traffic management areas, such as urban traffic control and public transport priority. Other areas, such as control of motorway traffic flow, used to be less advanced, but things have developed favourably during the last decade even in some of these areas and companies and authorities around the globe have been adopting or acquiring European motorway traffic management concepts and tools in recent years. The research areas identified in D14, and in particular within this theme, are opening new and innovative ways for Europe's science base, as far as the road transport area is concerned. The value of this innovative research is not limited to the mitigation of the currently faced transport-related problems, but extends to a genuine broadening of the societal knowledge and capabilities to address potential future problems and needs, in some cases even beyond the original specific application areas; clearly, this calls for inter-disciplinary, generic and systematic research and development approaches, rather than local or individual problem-fixing procedures. The accumulated knowledge and experience in traffic management issues over the last decades is vast. This knowledge must be fully exploited when addressing or designing a new generation of co-operative systems and management. Newcomers in the area of co-operative systems must be trained and become aware of this knowledge, so as to avoid occasional awkward attempts to handle anew issues of traffic management which have a long-standing history of developments and efficient solutions.

Large Scale management	Benefits	Challenges
NEARCTIS objectives	Faster incident handling Better management of environmental impacts Lower fuel consumption and pollutant emissions	Implementation results in over reliance on technology Need for better risk estimates Problems of equity for management measures Focus only on applications and not on theory
Horizon 2020 Priorities	Entry of large number of suppliers in the market Research on traffic assignment algorithms and other aspects of traffic modelling enhances European leadership	Intrusive use of personal data Ensuring consistent traffic information and advice Some residents will lose from the rearrangement of traffic Monopolies could emerge and SMEs could end up excluded

Table 3.6: Summary of benefits and challenges of large scale management

3.6.3. Summary

This research theme comprises several core areas of co-operative traffic management developments that offer the prospect of significantly improving the performance of today's road transport systems. Improvements are expected in the space-time extent of congestion (and the resulting journey times), in the environmental impact of road transport and in traffic safety. These improvements are expected to reduce significantly the societal resources that are wasted in traffic congestion. A successful outcome of the research proposed by NEARCTIS will also reinforce the top ranking of European research in the area of co-operative traffic management and will contribute to an increased competitiveness of European businesses in the transport sector and beyond.

Measures to meet one objective may have detrimental effects on other objectives. These trade-offs will need careful balancing. Traveller behaviour in terms of mode choice should also be an issue of analysis and investigation towards a globally optimal transport system. Equity considerations and constraints for individual groups of road users (or non-users) must be observed, so as to advance towards an efficient, but also fair service provision for all citizens. User acceptance and convenience is another prerequisite for effective traffic management. Appropriate training actions must ensure that the accumulated knowledge in the domain is preserved and exploited, not re-invented. Last but not least, an appropriate amount of funding should be reserved for the area of traffic management to enable and achieve a globally beneficial impact of significant technological advances in co-operative techniques and their application to reinforce the European excellence in the domain.

3.7. Support for policy developers, decision makers, managers and operators

The impact and worth of the NEARCTIS programme will ultimately be determined by the improvements in the operation of the transport system that it facilitates and encourages. The political will to deploy and use the outcomes of the research envisioned in D14 will be crucial to its realisation. The potential benefits of co-operative traffic management will require appropriate and relevant legislation and policies to be implemented. For this to happen, policy developers and decision makers will need to be properly informed and advised. Awareness of opportunities for application, the scope of technological development and capability, and the specific nature of benefits from implementation all form important elements of this support. Policy developers will need tools to identify possibilities, to assess the range of possible benefits, and ultimately to quantify them.

Better organisation of the urban environment towards the vulnerable modes of walking and cycling will enhance the experience and safety of travellers using them. This will promote their modal share and hence make organisation of the transport system more sustainable in both environmental and social terms. The research involved in this emphasises the fact that making the link between practitioners and researchers will promote the transfer of successful experiments into current practice. It will also increase the level of knowledge and understanding of leading traffic management techniques and evaluation methodologies among practitioners. Estimation of the effects on the operation and efficiency of the transport system will be important in establishing their value and supporting decisions to implement them. The benefits of this will include an increase in the efficiency of the transport system as a whole and an improvement in the travellers' experience. This work will also contribute to the environmental and societal agenda. The beneficial effect on safety, although more difficult to quantify, will also be valuable.

The previous sections of this report (3.1. to 3.6.) have each assessed the research themes alongside the objectives for NEARCTIS and Horizon 2020 priorities. This section differs in that its focus is on the objectives themselves and the research needed to provide support and advice for policymakers, decision-makers, mangers and operators. These categories of users of research each have different requirements. For example:

- Policymakers need evidence on the impacts of co-operative traffic management in general to support their policies on support (or otherwise) for this topic.
- Decision-makers need advice on which co-operative traffic management applications to pursue. This requires (1) evidence of effectiveness of these applications, bearing in mind the stated policies (European, national, local) and (2) advice on how these applications should be evaluated.
- Managers need to know how to implement the selected applications most effectively in an integrated way, which will require advice on optimisation, and
- Operators need clear guidelines for the effective day-to-day operation and maintenance of the applications they control.

An important aspect here will be the compilation of an evidence-base of results from Field Operational Tests (FOTs) and more permanent implementations as they occur, related to both the application and its context (functions, scale, location *etc*). The requirement here is that the field trials are undertaken according to best practice guidelines so that statistically sound results can be established. Such guidelines are already available for FOTs from EC-funded research.

Before field trials are undertaken there is normally a requirement to undertake a 'desk-top' evaluation of the proposed application(s) to identify their costs and benefits, and often to seek to optimise each application and its related strategies or parameters before implementation on street. In principle there may be a variety of ways to do this, ranging from analytical and mathematical studies, through microscopic simulation studies to full-scale dynamic network assignment models or their equivalent. The key is to choose the evaluation method which is most appropriate to the application being evaluated, based on its characteristics and expected impacts - and to recognise the limitations of the method.

3.7.1. Objectives identified for NEARCTIS

Safety It is clearly important for all the areas proposed by NEARCTIS for research to incorporate an evaluation of safety. The form of this evaluation will depend on the application; where the focus of the application is to improve safety (*e.g.* in-vehicle driver assistance system), then this has to be the focus of the evaluation using, for example, a simulator and/or an instrumented on-road vehicle prior to full implementation. Microscopic traffic models are currently not well developed to evaluate safety - this is a specific area of research recommended by NEARCTIS.

Where the focus of the application is not on safety (*e.g.* it may be on operational efficiency), then system design, implementation and maintenance would need to be undertaken using statutory regulations for safety, so that the application is, at worst, safety neutral. However, an application targeted at improved traffic efficiency (for example) can also enhance safety. For example, an effectively managed motorway may reduce flow breakdown and consequent 'nose-to-tail' crashes; or an improved journey time could lead to less exposure to accident risk. On the other hand, improving traffic efficiency can release suppressed demand and generate additional traffic which, overall, could lead to increased numbers of accidents. It is therefore recognised that any tool (*e.g.* microscopic simulation model) used for evaluating transport efficiency gains should also have a safety prediction capability.

Environmental impacts The research areas identified in NEARCTIS mainly target efficiency improvements and their underlying technical requirements, such as improved modelling and communications systems. However, as with safety, many of these efficiency-related applications will also have secondary environmental impacts. The tools used for evaluation, such as microscopic simulation models therefore have to have environment prediction capabilities (fuel consumption, local pollutants, global pollutant *etc*). This is a research area already identified in NEARCTIS - both concerning ‘increased data availability’ and ‘improved modelling at all scales. Wider than this, there may be a requirement to identify all of the potential environmental impacts of the application and use the appropriate evaluation process for their quantification (*e.g.* Environmental Impact assessment (EIA)).

Efficiency of the Transport System As noted above, the research areas identified in NEARCTIS mainly target efficiency improvements and their underlying technical requirements, such as improved modelling and communications systems. Evaluation of these areas will typically require the use of appropriate microscopic simulation and/or network wide traffic modelling. Again as noted above, this modelling should be capable of predicting the associated safety and environmental impacts, where these occur. Key to the use of simulation for co-operative traffic management applications will be its ability to:

- Represent the functions of the new application (data transfer, strategy modification *etc*)
- Represent the drivers’ and travellers’ behavioural responses to the new application, and
- Represent the impacts of these new functions and behavioural responses on system performance.

Within these modelling requirements, model calibration and validation using appropriate empirical data will be key components in developing a credible, robust model,

Traveller and system user experience It will be important for new co-operative traffic management applications to generate a positive traveller and system user experience, if there is to be ’buy in’ to the new facility. Pre-implementation evaluation of this impact will typically require a combination of questionnaires with users and stated-preference surveys. Gauging users’ actual experience of a new system obviously requires post implementation questionnaires and/or revealed preference surveys.

Societal impacts, costs and equity A better and more efficient transport system will contribute to a more sustainable environment. To evaluate societal impacts and costs pre-implementation, it would be usual to undertake a social cost-benefit analysis (CBA), using well established principles for economic evaluation. Inputs would typically be the relevant outputs from the traffic modelling, whilst outputs can be various measures of economic return (*e.g.* Net Present Value), relating to (at least) savings in travel time, safety and vehicle operating costs. Evaluating equity issues would require additional analyses of such factors as cost, accessibility, public and private transport availability and the distribution of impacts, especially the adverse ones.

3.7.2. Horizon 2020 Priorities

Societal Challenges Transport presents one of the major societal challenges in the next decade - particularly concerning energy consumption and conservation of fuel supplies, reducing the environmental impact, improving road safety and providing accessible and affordable forms of transport. All Governments recognise these challenges, and many recognise that further construction is not necessarily the answer as this can generate even more traffic and associated problems. The need with land transport is to make best use of our existing road space and this involves advanced co-operative traffic management and 'intelligent mobility'. So it is clear from this short commentary that the NEARCTIS proposals are directly complementary to the Horizon 2020 priorities that the research must address societal challenges.

Industrial Leadership An efficient transport system is essential for continued competitiveness of the EU. The tools and support developed as part of the proposed research will help to achieve a more efficient system.

Europe already arguably leads the world in the quality of its traffic management systems and their supporting research and development. Maintaining this competitive advantage cannot be taken for granted - it will require investment at the European level to continually enhance and improve our traffic management systems, particularly in the directions recognised in the NEARCTIS research themes. This will benefit a range of industrial concerns and SMEs through the manufacturing and export potential generated by these leading-edge technical developments. It is clear that the transport problems being faced in Europe are becoming increasingly common also in other parts of the world, so the NEARCTIS recommendations for research and development are clearly consistent with the competitiveness aspirations set out for Europe in Horizon 2020.

Advances in ICT are continually generating new opportunities for the involvement of SMEs. One such opportunity in the near future will undoubtedly be advances in Intelligent Transport Systems, as we look to new solutions for transport problems. As already noted, in-vehicle systems, traffic management and co-operative systems will be key elements in these solutions.

Excellent Science The development of the effective co-operative traffic management systems proposed by NEARCTIS will have to be underpinned by fundamental scientific research in a number of areas, including traffic flow theory, data fusion, mobile communications and real-time control, to name but a few. Europe has a leading academic and scientific capability in these areas, including the institutions represented in NEARCTIS for traffic management. EC investment in the research topics proposed by NEARCTIS will undoubtedly satisfy this key objective of Horizon 2020 - strengthening Europe's science base.

3.7.3. Summary

This section has outlined the type of support needed by particular user groups - policy developers, decision makers, managers and operators - to take forward the co-operative traffic management applications proposed. This support ranges from evidence of impacts, through advice on pre-implementation evaluation, such as the use of driving simulators, on-road instrumented vehicles and microscopic simulation modelling, to guidelines on implementation, optimisation, maintenance and monitoring of the systems. The importance of robust Field Operational Tests (FOT's) is stressed to provide evidence of impacts and effectiveness. The section then summarises potential methods for evaluation of applications against the five NEARCTIS objectives and three Horizon 2020 priorities. It is concluded that methods are available for evaluating against all of these objectives, but that some are much less developed than others, implying the need for further research on specific aspects of systems evaluation.

Support for policy makers	Benefits	Challenges
NEARCTIS objectives	Tools for evaluation of proposed measures Better understanding of the safety and environmental impacts Improved cost-benefit analysis	Ensuring tools are easily usable by intended targets Ensuring information is presented in useful and helpful forms Ensuring the limitations are understood
Horizon 2020 Priorities	Wider take up and implementation of beneficial traffic management policies Opportunities to export policy making and design expertise to the rest of the world	Tools, data use need to integrate into the policy formulation and decision making processes Investment needed

Table 3.7: Summary of the benefits and challenges of support for policy makers

4. Analysis of NEARCTIS Objectives

A review of the major long-term challenges for the EU in traffic management yielded a thematic view with the consequent opportunities for contributions from cooperative ICT (cICT). This led the NEARCTIS consortium to identify the following five key objectives of research on cICT in transport:

1. Safety
2. Environmental Impact
3. Efficiency of the Transport System
4. Traveller and System User Experience
5. Societal Impacts, Costs and Equity.

These objectives are all viewed as important and having similar priority. Further objectives that are also relevant include accessibility, economic return, livability and sustainability, which can be incorporated within these five key objectives. Different research themes, and hence potential innovations, will have differing profiles of contributions to this agenda.

In this chapter, we consider how each of these objectives will be promoted by research that is proposed in the Harmonised Research Programme. We proceed by exploring and summarising the contributions that are likely from the various research themes that were presented in Section 3. In particular, for each of these objectives, we identify the research themes that have the potential to contribute most to them.

4.1. Safety

Expected improvements to transport safety are prominent among the opportunities for cICT in transport within ITS. Although the general consensus is that safety is of particular importance, there is also agreement that it should not be considered to the exclusion of the other key areas. Instead, we suppose that innovations and interventions should be considered provided that they are at least as good as safety-neutral. Thus an innovation or intervention could be justified on grounds other than safety benefit provided that it is not expected to be detrimental to safety.

Potential improvements in road safety arise from a large number of measures to which cICT can make a key contribution in passive or active safety. The development of safety-related applications will depend on the timely availability of reliable data. Users will trust in warnings, advice and guidance only if the information is correct and is transmitted at an appropriate time and to an appropriate location where it applies. An indirect contribution of this research theme is therefore the development of quality concepts for the timely provision of reliable data and information. Opportunities for this include:

- The collection and supply of real-time information about relevant road, traffic and weather conditions, especially where these result from incidents or give rise to other transient hazards. In particular the use of in-vehicle sensors to gather information that can then be transmitted upstream using communication from vehicle to vehicle (V-V) or bidirectionally between vehicle and infrastructure (V-I-V).
- The supply of information and warnings regarding road geometry, layout and other static hazards.
- The supply of information about speed limits, permitted manoeuvres and other traffic regulations.

The indirect contribution of this research theme is the development of quality concepts for the provision of reliable data/information.

The increased use of mobile communication has the potential to contribute to transport safety and to change the scene in this field. Direct benefits can be expected for management and analysis from advanced data collection techniques that will make available data from a wide range of sources. Direct benefits will accrue for users through provision of higher quality information and more prompt delivery. The increased use of mobile communications can facilitate the realisation of more advanced and efficient transport-safety-related services, including incident detection, warnings for accident prevention and timely emergency response. Several key applications have already been or are currently being developed (*e.g.* intersection assistance, eCall), while others are still being envisioned (*e.g.* cooperative signal control, safety systems for vulnerable road users). Moreover, mobile communications can further assist in the building of a comprehensive and accurate safety evidence base (*e.g.* more detailed automated accident records transmitted to a central database in real-time, monitoring of pedestrian trajectories to prevent collisions), allowing for better informed decision-making on accident mitigation measures. Additionally the prospect of providing short-term future traffic information such as road and weather conditions will also enhance safety for travellers.

However, it should be noted that the increased use of mobile communications and the integration of new messages within the driver's environment could lead to increased distraction from the driving task. Appropriate HMI safety rules will be required to manage this. Hence, it is important that increases in availability and usage of in-vehicle ICT is accompanied by further advances in the field of human-machine interface.

Improved modelling has both direct and indirect effects on traffic safety. More accurate representation of drivers and travellers' decisions can help in anticipating their likely actions and responses, and in estimating likely consequences for safety. This will promote effective management of safety in emerging conditions even before they became manifest in the form of accidents or critical situations: travellers can be advised and guided in ways that will limit their exposure to elevated accident risks.

Communication between autonomous systems can result in improved incident management based on integration of monitoring and information systems with control systems. An ability to detect incidents more rapidly and to react in a more coordinated way to their development will achieve substantial safety benefits. These will accrue both directly in terms of reduced collisions through improved vehicle safety systems (*e.g.* collision avoidance systems) and more rapid attendance to care for victims, and also indirectly through improved implementation of dynamic traffic management strategies.

Interactions and communication with individual vehicles can lead to safer driving by managing lateral position within lanes and spacing from the preceding vehicle. Assistance from intelligent systems can reduce the frequency and consequences of human error and hence of collisions, thus improving safety. Communication among vehicles offers the prospect to make traffic conditions safer by propagating information and warnings about downstream conditions. Some part of these benefits should be reserved for safety improvements alongside their contribution to other kinds of benefits such as speed of travel and traffic capacity. Where a collision has occurred, the intelligent systems will be able to communicate relevant information to be used both to inform emergency services earlier and more accurately, and to improve traffic management.

The effective management of large-scale transport systems can make important contributions to traffic safety in Europe and elsewhere, because there is a continuing need to further reduce the number of accidents, injuries and fatalities caused by road traffic. Achieving effective large-scale transport systems and their efficient usage can contribute to this in various ways, some direct and some indirect. A direct contribution to enhanced traffic safety is achieved by traffic management measures that focus explicitly on safety-related issues. For example, a significant ingredient and expected outcome of advanced incident management is the more rapid detection of incidents and accidents and the more efficient dispatching of rescue teams, where necessary. Another convincing example is the dynamic motorway signalling system, which has virtually eradicated all head to tail collisions on the motorways since the early 1990s where it has been implemented. Research addressing pedestrians and walkers as distinct entities of an urban multi-modal environment is another example where pedestrian safety is a primary and direct focus; various types of information systems warning drivers about adverse weather or pavement conditions are expected to significantly contribute to safer motorway traffic; similarly, several emerging on-board or cooperative systems can be directly exploited to benefit traffic safety; last, investigation of contributory factors to accidents on rural roads, along with the analysis of detailed data from vehicle position and motion records on conflicts, close encounters and near-misses, is a direct contribution to safer traffic conditions on this kind of road infrastructure.

On the other hand, traffic management actions aim at more efficient traffic operations on all kinds of road infrastructure, which is typically achieved if the space-time extent of traffic congestion is reduced. Traffic congestion is closely related with moving shock waves, which involve sharp braking for vehicles, as well as with stop-and-go phenomena, and the associated driver frustration and anxiety. In short, traffic congestion leads to a number of factors that are known to increase the risk for traffic accidents. Therefore, any congestion mitigation achievable *via* combined large-scale management is likely to also deliver corresponding indirect improvements of traffic safety. Another relevant aspect is the need to reflect in traffic management decisions the estimated current risk level on strategic roads and motorways based on available and future measurements and information. This calls for the development of appropriate and reliable risk indicators that may be directly used in active traffic management systems as a trigger for the application of appropriate measures (*e.g.* speed limits) that are known to reduce the accident risk. Available research results in this direction need to be reinforced and extended to consider emerging information sources aiming at more reliable risk estimation. It should be noted that, like most technological innovation, some envisaged advances in vehicle technologies, communications and cooperative traffic management may imply some risks for traffic safety and accident probability, *e.g.* due to driver distraction, confusion or over-reliance on technology. These risks should be addressed and minimised before and in the course of significant introduced changes in the expected driver functions.

It is clearly important for each of the research themes as proposed by NEARCTIS to incorporate an evaluation of safety. The form of this evaluation will depend on the application; where the focus of the application is to improve safety (*e.g.* in-vehicle driver assistance system), then this has to be the focus of the evaluation using, for example, a simulator and/or an instrumented on-road vehicle prior to full implementation. Microscopic traffic models are currently not well developed to evaluate safety; developing this capability is a specific area of research that has been identified and recommended by NEARCTIS in the Harmonised Research Programme.

Where the focus of the application is not on safety (for example, it may be on operational efficiency), then system design, implementation and maintenance would need to be undertaken using statutory regulations for safety. Accordingly, any application to be introduced should be expected at worst to be safety neutral. However, an application targeted at improved traffic efficiency (for example) can also enhance safety. For example, an effectively managed motorway may reduce flow breakdown and consequent rear-end collisions; or an improved journey time would lead to reduced exposure to accident risk. On the other hand, improving traffic efficiency can release suppressed demand and generate additional traffic which, by increasing exposure to risk, could lead to an increase in the numbers of accidents. It is therefore recognised that any tool (*e.g.* microscopic simulation model) used for evaluating transport efficiency gains should also have a safety prediction capability.

4.2. Environmental Impacts

Mobile communications has the potential to reduce the environmental impacts of travel in several ways, both direct and indirect. The effect of vehicle emissions on the local environment and population can be used within the calculation of routes to be recommended to drivers. Effective mobile communications will be required to deliver the results of this to drivers in order to influence their behaviour. We anticipate, however, that the primary benefits for the environment of increased use of mobile communications will be indirect. Given that mobile communications have the potential to improve transport system efficiency, we expect that vehicle to vehicle communication will help to bring about smoother traffic flow and infrastructure to vehicle communication will help to reduce vehicle-distance of travel through increased public transport patronage, greater use of shared vehicle systems and higher modal shares for the non-motorised modes walking and cycling, with consequent reduction in fuel consumption, and emissions of pollutants and noise. Another possible application of mobile communication that could help reduce environmental impacts is the use of software that advises on eco-friendly driving. In the past there have been vehicles that track fuel consumption and this could be input to software in the mobile communication system which will then give feedbacks to the drivers on his performance.

An indirect impact could be the reduced noise emissions perceived by residents due to the congestion relief that will occur through increased mobile communication and result in fewer engines running in a given road and potentially fewer conflicts, which could in turn lead to reduced sounding of horns. This leads to opportunities for management of traffic differently over space in time to respond to episodes of accute pollution, which are a function of traffic congestion, traffic fleets and meteorological conditions.

On the other hand, it should also be considered that the wider use of mobile devices and infrastructure may require greater energy consumption for their operation and greater use of natural resources for their manufacture, thus engendering a number of indirect negative impacts on the environment, which should be investigated.

Many approaches have been proposed for reducing the environmental impacts of road transport. Cooperative traffic management is one of the promising actions for reducing fuel consumption, improving air quality and avoiding traffic congestion in specific areas. The improvement of environmental conditions results from complex processes with the interaction of many subsystems like drivers, cars, infrastructures, built and natural environment. In this context, data management is a real challenge while combining different sources of information with challenging exchange of data.

The benefit of this research theme is that it will allow a better management of data flow and interoperability of road and traffic data within the context of an environmental data warehouse. Innovative metadata models will be available for environmental monitoring in interaction with traffic flow modelling. Tools for the aggregation of data and interaction with modelling are needed to support measures reducing environmental impacts. Therefore, these tools will support the measures for reducing the environmental impacts, which must be proportionate according to local, regional or national specificities. Data and models being equally important, this research will contribute to a better integration of environmental modelling and monitoring, knowing which model is more appropriate for a specific application.

This research area is broad and on-going activities are already focusing on the generic topic of data interoperability. Therefore it will be necessary to adopt some of the existing specifications and models (*e.g.* the INSPIRE directive, http://inspire.jrc.ec.europa.eu/), and to develop new concepts on this basis.

Several mechanisms are available to promote this objective. Having more detailed emission and air quality models is one; however, in addition, also better models that more accurately describe driver behaviour help to better estimate the emissions produced. Having estimated the flow of vehicles on each length of road, there are essentially three further modelling steps, with very different instruments to do it. The driver modelling is needed in order to establish the correct acceleration and speed of the vehicles, and the corresponding engine speed. From this, the emissions produced by the vehicle can be estimated, and this part of the task seems so far the one that is best understood. Last, the emissions produced will be transported and transformed, and analysis of this again is not an easy task because of the influence of detailed geometries of city streetscapes and the many chemical reactions involved. So, models can be used to estimate the emissions produced by the transport system at all scales and resulting air quality, from regional down to local scale. (Of course, they are already used for this purpose, but with limited and often unknown precision.)

Given the limited amount of emission measurement devices (a typical German city usually has only a handful of those emission measurement stations but greater numbers of air quality sensors are installed in some British cities), modelling helps to establish an emission and an air quality database for all those many place where there is no explicit emission measurement. This in turn helps to design possible countermeasures to lead to a transport system that minimizes environmental impacts as far as possible.

Finally, the planning processes may benefit from improved modelling. At this stage, environmental impacts are rarely taken into account in the design of new infrastructure, and if they are, they are taken only as a kind of post-processing, *i.e.* designs with lower environmental impact are preferred. These priorities can be interchanged: optimizing primarily in order to minimize environmental impacts, and only secondarily in respect of other objectives (resources, geometry, and travel time). Choices in optimization formulations can change the whole planning process profoundly.

Although not explicitly identified as a key focus, the research areas in differential road pricing and responsive optimisation could use communications between autonomous monitoring and control systems to optimise traffic against environmental impact objectives as well as economic objectives. If this approach was taken optimisation of traffic patterns against environmental criteria would be enabled alongside more traditional time/cost optimisations. It is recognised however that key to realising such benefits will be the creation of a comprehensive real time picture of traffic and environmental conditions (i.e. the level of data communication with environmental monitoring systems must match the level of communications with traffic monitoring systems) or else the risk occurs that the optimisation will simply relocate the current environmental impacts to alternative locations/times rather than achieve the desired reductions.

Intelligent vehicles are increasingly equipped with new technologies for adaptive cruise control (ACC), dynamic route guidance and hazard warning systems. These technologies may reduce fuel consumption and emissions by providing support at the operational level (ACC) as well as at the tactical level, when choosing optimal routes avoiding congestion. Often, intelligent vehicles are also equipped with hybrid and electrically powered units, having a direct impact on the environment. However, without explicit consideration of areas, which are preferably to be avoided (and hot-spots for that matter), rat-running may occur and increases in traffic flow where it is not desired from a liveability perspective may occur.

As for safety, a multi-scale controller functioning according to regional policy can explicitly take into account the necessary limitation in the use of specific roads in order to meet liveability norms (*via* the protected roads concept).

Increased cooperation between traffic control systems makes it possible to distribute the inconvenience from a local bottleneck over a larger area. Local effects of extra noise and emissions due to congestion may therefore be reduced, but be increased slightly at other locations. Also, personal travel support systems could take into account the functions of the different roads, and as such discourage drivers from using roads that are protected from the viewpoint of environment or safety.

As for safety, indirect environmental benefits may result as a consequence of improved efficiency of the traffic system as a whole, through which high accelerations (which have detrimental effects on both noise and emissions) are prevented.

The environmental impact of vehicle traffic (including emissions, noise and more) is another major concern of modern society, which is strengthened due to the potential impact of global warming. Again, improved traffic management for large-scale transport systems can be beneficial for the environmental impact of traffic, both directly and indirectly.

A direct benefit is achievable *via* appropriate quantification (modelling or measurements) of the incurred environmental impact and its explicit consideration (possibly in a multi-objective setting) as an optimisation, control and evaluation criterion in planned or operational traffic management actions; several recent research works have been developing the corresponding necessary modelling and optimisation tools. Since the environmental impact is aggravated in cases of very low vehicle speeds, rapid speed changes and vehicle acceleration, an indirect environmental benefit may result as a consequence of the space-time decrease of road traffic congestion that is achievable *via* successful traffic management. Mode shift towards non-motorised and other more environmental-friendly transport modes (*e.g.* walking, public transport), which may be triggered via, for example, a more pedestrian-focussed traffic management or road pricing, has also the potential of reducing the environmental impact of modern transport systems.

The spatio-temporal extent of congestion can justifiably be correlated with the environmental impact of a configuration of the road network and its traffic. However, a potential reduction of the prevailing extent of congestion may reveal some threats or countervailing effects that should be considered carefully. These threats may be related to the very nature of the envisaged traffic management action, for example due to slowing down some portions of the traffic flow (hence increasing their contribution to the environmental impact) to improve throughput for other portions. In addition, a decrease in travel delays may motivate travellers to modify their departure time or to shift to their car. For example, some recent studies indicated that improved signal coordination on arterials can, under certain circumstances, result in an increase in the environmental impact of the arterial traffic due to induced demand. Clearly, such statements should not be misunderstood as a discouragement from combating traffic congestion; but they underline the global character of the transport system that calls for consideration of inter-modal issues and appropriate trade-offs between different evaluation objectives.

The research areas identified in NEARCTIS mainly target efficiency improvements and their underlying technical requirements, such as improved modelling and communications systems. However, as with safety, many of these efficiency-related applications will also have secondary environmental impacts. The tools used for evaluation, such as microscopic simulation models therefore have to have environment prediction capabilities (fuel consumption, local pollutants, global pollutant, etc). This is a research area already identified in NEARCTIS - both concerning 'increased data availability' and 'improved modelling at all scales'. Wider than this, there may be a requirement to identify all of the potential environmental impacts of the application and use the appropriate evaluation process for their quantification (*e.g.* Environmental Impact assessment (EIA)).

4.3. Efficiency of the Transport System

Together with safety and traveller experience, the efficiency of the transport system is one of the fields in which the benefits of the increased use of mobile communications are expected to be greatest. Potential benefits for the system will come through the ability to maintain more effective monitoring and hence to manage road networks better, including the possibility to provide beneficial advice and guidance to travellers. Concerning direct impacts, these have the potential to be delivered primarily through advances in data collection, as the use of mobile devices as vehicle and passenger probes can supply a wide range of transport data, which include measurements and counts complementing existing detectors and sensors (*e.g.* traffic flow counts, speed and travel time measurements), but also data previously only collected on an ad-hoc basis or not collected at all (*e.g.* concentration of pedestrians at public spaces). Data of this form have the potential to increase transport system efficiency, either through supplying advanced traveller information and guidance to influence travel choices, or through advanced traffic management methodologies (*e.g.* multi-modal routing and assignment algorithms). Some preliminary applications have already been developed in this direction (*e.g.* Google Traffic), with others being currently under planning and development.

Nevertheless, a number of issues potentially delivering indirect adverse impacts with respect to transport system efficiency still need to be addressed. These include both technological deficiencies (*e.g.* how to distinguish a mobile device user's travel mode, how to track mobile probes underground), and also methodological problems (*e.g.* how to deal with the problem of balance between the interests of individual users and those of the system as a whole.)

One of the key aspects of the efficiency of the transport system is the optimal use of different modes according to economical and environmental criteria. For travellers, a smooth and continuous mobility is expected and has a deep impact on the perception of the system performance. Each transport segment has already implemented advanced management tools, mainly based on relational database and geographic information systems. However the efficiency is mainly optimised for a specific mode of transport, and accessing and optimising with respect to multimodal databases is still challenging.

This research theme will improve the interoperability of information systems with the development of new standards in communication, traveller information and exchange of data. One of the main advantages will result from the innovative concept of communication/exchange of data between transport systems and user community. The deployment of solutions independently of transport mode will increase the potential of data exchange. Therefore, multimodal route choice will be possible without break (gaps) between transport modes. This research will support continuity of service across the trans-European transport network.

Models are already used heavily to estimate the effects of new and prevailing control devices. However, when it comes to the effects that communication might have on the overall performance of the transport system, we still face a modelling gap. By several simulation experiments, it has been demonstrated that especially the communication between vehicles and between vehicles and infrastructure can help to improve the overall efficiency of the transport system. However, most of these simulation experiments only display an outcome that stems from somewhat artificial conditions. It is also necessary to avoid side effects Braess-like effects (assignment of traffic towards attractive but environmentally sensitive areas) and more generally to assess the retroaction of information and communication in the transport system. Having better models will help to estimate the benefits of such a cooperative traffic management in a more reliable manner. Given this, a better estimate of the benefits of a certain new policy may lead to additional improvements. Consider, for instance, the coordination between traffic lights. By making them much more traffic responsive, with data that are difficult to obtain by traditional means (*e.g.* travel times, delay times, vehicles may even inform the controller about their current emission or engine or battery state, a useful feature for use of electrical vehicles), more flexible and possibly more efficient control policies may be designed — itself a very interesting and fertile field of research.

This is a key objective of many of the research areas in the harmonised research programme that include communication between autonomous systems (*e.g.* Multi-scale traffic control, incident management and fleet management) and as such is anticipated to provide substantial advances in efficiency both directly for the fleets involved and indirectly for the wider traffic flows. The efficiency of the Transport System is expected to increase through the introduction of new technologies, the enhancement of current monitoring and the improvement in journey times measuring. The communication between autonomous systems is meant to facilitate the operation of new technologies and management of data. One of the dangers related to the use of various different autonomous systems is the possibility of data inconsistency.

Different characteristics of hybrid and electrically powered vehicles may change the road capacity, as well as traffic flow stability, and thus the efficiency of the transport system. Furthermore, it is well known that individually optimized choice behaviour stemming from individual route information and advice will not yield a situation which is optimal from a system perspective (differences in collective travel time losses up to 30% can occur, but are often smaller (Peeta, 1994).

Increased cooperation between traffic control systems increases the control space and thus the opportunities to solve congestion in an area. A good example of this is coordinated ramp-metering, where the additional storage space provided by the upstream ramp-meters is used to enable longer and thus more efficient metering. This will have a positive effect on the efficiency of the transport system. This positive effect does not only relate to travel times, but also to travel time variability, as the predictability of travel times will increase and travel times are known to vary more in situations near capacity.

Cooperation between the traffic management system for regional traffic management (such as currently used in the Amsterdam region, using traffic management scenarios to determine which combination of measures are to be deployed under specific conditions) and in-car systems should lead to additional efficacy of the traffic management, information and control. First, the in-car system provides valuable data to improve traffic management as well as to advance data collection in general as the in-car system can supply a wide range of transport data. Second, traffic management information and guidance will be send to individual vehicles (*e.g.* delay times due to ramp-metering, or changed signal control settings) yielding better information and allowing the road-users to change their route if they wish.

The daily congestion plaguing metropolitan road and motorway networks during the peak periods or in case of serious incidents is a major threat for the economic and social life in modern societies due to the incurred over-long delays and other detrimental impact related to safety and the environment as mentioned earlier. The prevailing traffic situation on our road infrastructure during the peak periods or abnormal events degrades the nominal capacity of the infrastructure and incurs an excessive multi-faceted societal cost. Traffic management actions have traditionally attempted transport efficiency improvements *via* a better or even optimal utilisation of the available road infrastructure that is deteriorated due to vehicle queuing and congestion. Most large-scale management measures address transport efficiency directly for motorways (incident management, ramp metering, variable speed limits, integrated motorway traffic control) or for urban road networks (improved network-wide signal control under saturated traffic conditions, gating) or for mixed networks within corridors. Advances in methodological (control, optimisation, integration and coordination) and technological (*e.g.* cooperative systems) areas and new applications (*e.g.* road pricing), if properly exploited, may lead to, in some cases substantial, improvements in terms of congestion mitigation and delay reduction. A more holistic approach, addressing different transport modes simultaneously, may deliver further and more balanced improvements for the overall metropolitan transport system; clearly, this is a major challenge that calls for substantial innovations that reach, beyond technical developments, the administrative and political levels.

As noted above, the research areas identified in NEARCTIS mainly target efficiency improvements and their underlying technical requirements, such as improved modelling and communications systems. Pre-implementation evaluation of these areas will typically require the use of appropriate microscopic simulation modelling and/or network wide traffic modelling. Again as noted above, this modelling should be capable of predicting the associated safety and environmental impacts, where these occur. Key to the use of simulation modelling for co-operative traffic management applications will be its ability to:

- represent the functions of the new application (data transfer, strategy modification, etc)
- represent the driver/traveller behavioural responses to the new application, and
- Represent the impacts of these new functions and behavioural responses on system performance.

Within these modelling requirements, model calibration and validation using appropriate empirical data will be key components in developing a credible, robust model,

4.4. Traveller and system user experience

Great benefits are expected from the increased use of mobile communications with respect to traveller and system user experience. Greater levels of information will allow better decision making on the user's side and thus promote the safe and effective use of the transport system. Given that the vast majority of users are equipped with some kind of mobile device, primarily smartphones but increasingly also other devices, such as tablet computers and connected in-vehicle units, dissemination of sophisticated traveller information and guidance is becoming more straightforward, resulting from the collection of more advanced traffic data and complementary data from other sources such as social networks. Through mobile communications travellers have access to more advanced and customised travel services (*e.g.* real-time traffic and public transport information, multi-modal trip planning, online taxi booking, parking space finding), thus receiving better customer service. In particular, dynamic, flexible and personalised mobile communications can be used to promote public transport as a fast, reliable, safe and comfortable (in contrast to popular belief in many cities worldwide). Mobile communication is one of the channels for the provision of advanced traveller services. The advantage of mobile, location-based services is their capability to deliver information in real time.

They will also help to support the sustainable travel modes of walking, cycling and shared vehicle systems by making their use easier (*e.g.* through integrating bicycle sharing in trip planning, providing information on bicycle availability, and facilitating booking of bicycles and docking stations for them).

Through this, mobile communications can improve traveller and system user experience, both directly through access to transport services on-the-go, and indirectly through better transport system efficiency, better safety and better quality of life. Nevertheless, indirect side-effects (such as information overload) should be considered. Also more research should be carried out on how to convert the data into knowledge for decision makers and also to be given to the public to help them to make informed decisions.

Traveller and transport users feel more comfortable when they receive reliable information on the status of the transport system. In case of incidents, it is necessary to send appropriate and timely information to users who need to change their plans or to search for alternative mode of transport.

This research theme will provide solutions for high integration of traffic and traveller information. In this concept, many information channels can provide contradictory messages to users. Quality check tools will help operators in the formulation of reliable and adequate messages according to multiple sources of information. This research will support maturity which is highly required for the deployment of robust ITS services accepted by the user community. A better knowledge of data sources, especially with the integration of destination information, will allow creating much more accurate and adequate information for the users.

Most of the effects of improved modelling on the user experience are indirect. Better models mean not only knowing better the current state of the system (real-time estimation) but also capturing better the short-term future traffic conditions. Since this information can be shared in a cooperative transport system with the users, they can use this information either to change and adapt their travel plans, or, if they do not do that, they are at least more comfortable with knowing what is going on, which has been shown to be an important added value of information.

The indirect route is that a better modelling can also better anticipate the most likely reactions of the travellers and users, and this will help to design policies that have a better level of acceptance as well as being more effective. This in turn improves the reliability of the measures, which again improves the acceptance by the users at least in part— as long as they are too adversely affected by the improved control policy.

Although the direct impacts of the autonomous system communications research on the experience of individual travellers will be limited, the better understandings and transport network management that results could be expected to reduce delays and improve the quality and accuracy of traveller information. However, a risk in this is the possibility of unstable feedback between traffic state and traveller information systems. The understanding of the current network state increases in temporal and spatial resolution through greater communication between different monitoring systems. If such information is going to be disseminated more rapidly and more widely through better communication with real time information systems, then the risk that occurs is that increasingly large proportions of travellers will choose to react spontaneously to new information leading to sudden swings in traffic state. Traveller experience will be enhanced by greater higher reliability and speed of dissemination of information facilitated by improved communication.

Experience with as well as the maturing of intelligent systems will improve user acceptance, and thus increase their penetration grade over the coming years. User experience and acceptance will also affect the choice and further development of functionalities in the intelligent vehicles.

Interaction between the centralized traffic management system and in-car (information) systems should improve information provision to road users substantially, not only providing actual and accurate information on traffic conditions, but also on the status of the traffic management measures. Moreover, this form of interaction should lead to consistency in information provided *via* different channels (roadside, in-car, *etc*.) leading to improved user-acceptance.

Higher levels of coordination with the capability to impose choices upon drivers may lower public acceptance, due to their reduced freedom of choice to choose any route or departure time. Here, enforcement would come into play, to make sure that traffic management measures were indeed followed.

The commuter and, more generally, the traveller on the transport system have a number of interests and quality criteria which include: short (if possible, zero) delays; journey time reliability (similar journey times for the same trip at the same period of day) for proper scheduling of his or her activities. Before a joiurney, reliable and convenient ; multi-modal information for proper and efficient mode and route choice; on-trip reliable information and recommendations, particularly in case of abnormal events, for efficient real-time route and mode (*e.g.* park-and-ride) choice. In particular, journey time reliability is a specific user criterion that has been largely neglected in past developments, but seems quite crucial for the efficient planning of transport of persons and goods. The traffic flow behaviour, particularly in saturated traffic conditions, is known to exhibit some chaotic characteristics, whereby small changes in demand or supply may lead to large changes in journey times. Feedback control is a well-known way to reduce chaotic characteristics, thereby improving the journey time reliability under normal peak-period traffic conditions. On the other hand, increased reliability under abnormal (*e.g.* incident induced) traffic conditions implies proper user information and fast implementation of control measures to mitigate the related delays.

Large-scale traffic management measures must address these traveller concerns sufficiently and improve user experience and choices. Appropriate user campaigns may be necessary in some cases to enable or increase user acceptance and proper use of innovative systems. Enforcement, particularly for innovative or critical traffic management interventions, is another complementary aspect for better efficiency and more compliant user experience. Last not least, special user groups (*e.g.* elderly or handicapped people) may need special attention in the implementation of particular traffic management measures and actions. A potential threat in this context is the decentralisation of services (*e.g.* provision of information) by multiple providers with partly different scope, interests and target groups. This trend, which is facilitated by available or emerging technologies and information sources, may, under certain circumstances, contrary to the apparent need for more global, integrated and transparent approaches to the modern transport requirements and may call for appropriate coordination and regulation actions to ensure synergy and harmonious cooperation of sub-systems.

It will be important for new co-operative traffic management applications to generate a positive traveller and system user experience, if there is to be 'buy in' to the new facility. Pre-implementation evaluation of this impact will typically require a combination of questionnaires with users and stated-preference surveys. Gauging users' actual experience of a new system obviously requires post implementation questionnaires and/or revealed preference surveys.

4.5. Societal impacts, costs and equity

The increased use of mobile communications is likely to have important positive direct and indirect benefits to society, costs and equity. Namely, connected mobile devices can offer access to personalised mobility information and services, which will be especially valuable for elderly and disabled road users. Examples of these services include dial-a-ride and multi-modal step-free-access trip planning. This will promote affordable mobility in deprived communities, thus enabling access to activities, preventing social exclusion, and ensuring equity for these social groups. Moreover, mobile communications can be a valuable tool for providing customised transport-related options to a wide range of social services (*e.g.* real-time routing for police, fire brigade, emergency vehicles).

In a broader sense, mobile communication can be a driver for facilitating sustainable and seamless mobility in urban and rural environments, thus helping to improve the quality of life. However, research should also investigate potential adverse effects of mobile communication, arising from low technological engagement of certain societal groups (*e.g.* elderly) and risk to travellers' privacy.

The wide dissemination of mobile communication and information is a reality, and privacy issues are becoming more and more critical (*e.g.* see legal action against Carrier IQ). Users have no trust in non-transparent and intrusive services. There is always a risk of non explicit use of personal information (*e.g.* location-based service) .

This research theme will promote open solutions and tools for using and accessing data according to rules and best practices in order to guarantee privacy. The result of this research will promote the equity of access to ITS services based on appropriate data management which takes into account existing rules, policies and legal aspects. Robust tools for data quality management will be an advantage for service providers who can optimise costs of services with more reliable information.

Improving the safety and reliability of the transport system leads to positive societal impacts, as long as one controls in addition for the protected areas. This might not be really difficult, since more often than not the protected areas are not particularly attractive to through traffic. Of course, there exists a kind of critical threshold when too much traffic gets diverted to too few main routes, when it becomes more attractive to move through areas that should be protected from additional traffic. Again, how to stay well below such a threshold is a feature that can be estimated with improved modelling. However, other measures could be implemented to support the proper control of the traffic flow, such as for example a toll that is based not on the time of the day, but on the ”protectedness” of the area under consideration. Once more, this might only be achievable with the additional communication means that comes with a cooperative transport system. Furthermore, the estimates delivered by the improved modelling also act as indicators to help to achieve a sustainable urban environment. Models can also help to assess and improve the equity of various aspects of the transport system.

With the possible exception of the differential road pricing research area, this is not a key objective of the proposed autonomous systems communication research areas, but some indirect benefits will arise through (for example) improved reliability and safety, and reduced environmental impacts. There are also indirect drawbacks falling upon users and residents (*e.g.* noise and environmental impacts). It needs to be assured that both advantages and disadvantages will be distributed among individuals in a fair and equitable way.

Improved throughput, reliability, safety and liveability have obvious positive societal impacts. The costs of setting up the interactions required to bring these about stem from: 1) research and development; 2) technically enabling current systems for interaction with a supervisor, and with in-car systems and 3) operational cost of running and maintaining these systems. Some of these costs are for the road authorities, and some are for private companies (service providers, in-car hardware manufacturers, etc). Public take-up is an immediate issue only for the use of in-car information, of which the cost will be the most determinant factor. This may result in a situation where only a some of the travellers are actively using the information provided, which may lead to some form of inequity.

Another aspect of equity relates to which road users will suffer delays, depending on the choice made by the traffic management system where to distribute which traffic. Vehicles in initially unhindered areas will this way encounter delays which they would not have had if no traffic management had been performed.

The European Commission estimates the annual road congestion cost to be about 120 billion €or 1% of the European Union’s GDP. This is a cost suffered by private road users, companies and state institutions and does not include the environmental impact and traffic safety losses. Any improvements achieved *via* the envisaged research work on large-scale management will affect this cost directly and will contribute to more liveable conditions for metropolitan areas. Equity is a particularly sensitive criterion and can be addressed in at least three different ways: First, the envisaged managed road infrastructure should provide for reasonable fairness in terms of journey times of different road user groups; for example, the delay of metered vehicles at motorway on-ramps (or of vehicles entering an arterial from a side-street) should not be allowed to increase excessively for the sake of the, clearly more significant, mainstream (or arterial) traffic; more generally, traffic management should enable similar journey times for equal-distance trips (connecting any origins and destinations) within a sub-network, although with sufficient care, as this requirement may often contradict the minimisation of the total time spent by the whole driver population. Secondly, equity and fairness may address road users belonging to different income groups; some traffic management measures, such as road pricing, may in some cases be perceived as an advantage for road users with higher income, which may necessitate appropriate compensating measures, *e.g.* the provision of high-quality transport alternatives (such as enhanced public transport or public transport priority measures) . Finally, a more broad view of equity may be considered, so as to include not only the actual travellers, but also the citizens (possibly non-travellers) who are affected by traffic and transport, for example because of their living, working or walking locations; this last class falls under the general issue of environmental justice or equity. Another challenging issue in this context is the share of the innovation cost. For example, in-vehicle systems, which enable the implementation of several cooperative functions at the traffic management level, will have to be paid for by their owners; such a scenario, however, implies special benefits for the owners as a motivation to purchase the systems in the first place. The situation is likely to become more complex with the involvement of vehicle fleets of various kinds, various commercial service providers etc. Although the corresponding challenges may be deemed more economic or even political than technical, they may have strong implications for the pursued technological solutions, their targets and their implementation procedures.

A better more efficient transport system will contribute to a more sustainable environment. To evaluate societal impacts and costs pre-implementation, it would be usual to undertake a social cost-benefit analysis (CBA), using well established principles for economic evaluation. Inputs would typically be the relevant outputs from the traffic modelling, whilst outputs can be various measures of 'economic return' (*e.g.* 'Net Present Value'), relating to (at least) savings in travel time, safety and vehicle operating costs. Evaluating equity issues would require additional analyses of such factors as affordability, accessibility, public/private transport availability, etc

5. Horizon 2020 priorities

The European economic uncertainty evident since the 2008 financial crisis has produced many impacts within the Union; these impacts however, have exacerbated and accelerated present trends. For instance, by 2007 it was foreseeable that, in the long run, ageing Europe would fall behind the emerging economies. According to the EU programme FELICIE, within 30 years the age dependency rate, *i.e.* the ratio of persons age 65 and over to the population aged 15-64, will exceed 40 percent by 2030 and 50 percent by 2050, substantially above the world rate of about 25 percent. In addition, we can observe that in Europe strong tensions exist in relation to high levels of unemployment among young people and immigrants, whereby both groups are extremely vulnerable to structural changes in the economy. The crisis is now accelerating this trend, driving down the activity rate in the EU 27 by three percent between 2006 and 2010. The differences in the performance of Member States since 2007 have shown that resilience to the crisis is conditioned by a range of national policies, and not only those of a financial nature.

Against this background, the EU is strengthening its commitment to integration and cohesion and the Horizon 2020 programme, the Union's new funding programme, reflects this necessity to deliver ideas, growth and jobs for the future. The ideas and approaches proposed by NEARCTIS can certainly provide a stimulus for achieving the Horizon 2020 objective such as closer convergence of communications across the European Union. In this section we will examine the three main priorities of the programme and show how they can be related to NEARCTIS research objectives.

The three main priorities of Horizon 2020 are:

1. Societal Challenges
2. Industrial Leadership
3. Excellent Science.

The societal challenges priority (1) is an umbrella under which we can identify six societal challenges which require inter-disciplinary co-operation in their analysis and thus integrated approaches. ICT represents one of the major tools for fostering smart cities in order to plan, monitor, control and safely operate interoperable networks in an open and competitive market. Smart, green and integrated transport is a main challenge within this priority which aims to realise transport systems that are resource efficient, environmentally sustainable, safe, and that support inclusive societies. Addressing such challenges will require innovative and advanced industrial technologies which will boost the role of Europe as leader. The EU industrial leadership (2) will be defined to increase competitiveness by stimulating business, including SMEs, towards advanced technology applications. Horizon 2020 will support innovation research to attract particularly small and medium enterprises which through competitive dynamics will be able to develop industrial strategic alignment between EU and private resources. In this context, smart finance as well as new financial mechanisms will play a fundamental role in order to develop a robust and mature market where the feedback loops between implementation and research and innovation will constitute the framework for optimal financial resource allocation (Kline and Rosenberg chain-link model). The seamless support from research to innovation, from idea to market is based on quality research (3) that the programme Horizon 2020 aims to operationalise. The priorities in the programme will be identified by scientists and thus the work of NEARCTIS is fundamental to the constructing of instruments with clear added value and high impact. NEARCTIS serves primarily as an enabler of future application-focused research in its field of expertise, and in the following sections we will examine the different NEARCTIS objectives under the three main Horizon 2020 priorities.

5.1. Societal challenges

Co-operative ICT offers many opportunities and will provide many social benefits. However there are also challenges to be met. The essential rôle that of mobile communications has challenges for equity and privacy. Access to the required mobile communication devices should be available to all. This means that the technology has to be affordable and not requiring expensive devices for its use. The interface design must approachable and easy to use, particularly for elderly and disabled road users. Wide spread and extensive collection of data is needed for many envisaged applications. The crucial challenge that will arise is convincing the public that there will be no intrusion into personal data. People should be assured that their personal information will remain anonymous, not be accessible by others and not be used in unexpected ways.

One of the goals under the umbrella of ”societal challenges” results in promoting interdisciplinary co-operation involving generic technologies, sciences and interactions with the relevant policies. This context is particularly favourable for the development of novel research on data quality management and data fusion. Semantic and conceptual data modelling are fundamental pillars for interdisciplinary research and development. The use of model-driven (object-oriented) approaches is a key aspect for promoting common language among disciplines. This will improve the perception of some phenomena in our society across different fields including technology, social sciences and humanities.

The consequences of autonomous interaction systems may have social benefits such as differential road pricing but also present challenges. A significant challenge will arise in making sure that route guidance does not lead disproportionately to costs and inconvenience on some residents in terms of congestion and traffic-induced noise and emissions.

Understanding interactions at various levels will bring social benefits of efficient transport, less congestion and more safety, while at the same time reducing the impact on the environment and reduce the dependency on fossil fuels. It was argued that higher levels of interaction and increased co-operation and integration will lead to a more efficient, greener transport system. In this respect, the transport challenge (smart, green, integrated) is met. Not only the pure reduction of congestion, but also its distribution over a larger area can in suitable circumstances be made to result in benefits for a larger part of the population if the negative effects for both traffic participants and people living in the neighbourhood are distributed so that the number of gainers exceeds the number of losers.

Despite the undeniable advances achieved in the recent past, sensible innovation is a prerequisite for more radical solutions, and this may call for paradigm changes, not only with respect to the employed traffic management methodologies and technologies, but also with respect to the research, development and deployment approaches and procedures. Research work on advanced traffic management should consider more explicitly the related practical and administrative concerns. It should be emphasised, however, that attempted improvements in this vital area of modern human activity call for more than merely technical innovation; the organisational, administrative and political environment should facilitate the actual deployment of practicable innovative approaches.

Transport presents one of the major societal challenges in the next decade - particularly concerning energy consumption and conservation of fuel supplies, reducing the environmental impact, improving road safety and providing accessible and affordable forms of transport. All Governments recognise these challenges, and many recognise that further construction is not necessarily the answer as this can generate even more traffic and associated problems. The need with land transport is to make best use of our existing road space and this involves advanced co-operative traffic management and 'intelligent mobility'. Ensuring the effective update and deployment of these advances requires not only the technical advances envisaged by the main thrust of the Harmonised Research Programme but also the tools to support policy developers, decision makers and managers. Only with this support will the research provide the expected benefits and so contribute to the transport-related societal challenge in Horizon 2020 of the goal of a smarter, greener, and more integrated transport system that supports a sustainable development within Europe.

5.2. Industrial Leadership

The resaerch programme proposed in NEARCTIS deliverable D14 will generate contributions at the forefront of knowledge and technological development. This is especially so within some of the themes such as improved modelling. This raises the challenge to develop a common European vision of this subject area alongside that in the USA through programmes defined and sponsored by the FHWA and the TRB to provide national focus in development of simulation and modelling tools.

The expected impacts from the increased use of mobile communications in the area of competitiveness and SMEs are positive but mainly indirect, as the latter is a side-effect rather than a goal in this case. Specifically, it is anticipated that increase in demand from the greater number of users will prompt the entry of a larger number of suppliers of mobility-related online products and services into this already rapidly expanding market, thus inducing a shift from the traditional model of state-sponsored monopoly of transport products and services to a highly competitive environment. SMEs are likely to benefit greatly both from a highly competitive market for online mobility products and services, which they can enter with low start-up costs, and also from a growing body of related research and innovation in which they can play a prominent role as beta testers and end users. However this does not by itself guarantee high quality of provision in respect of coverage, reliability and accuracy.

Multiple sources of data, contradictory information and limited exchange of data are reducing the competitiveness of SMEs and the deployment of new services. Fast and open access to data is a fundamental support to innovation which requires an efficient data warehouse with advanced models. This will enable the sharing of information among service providers and public and private organisations. It may also help to provide users with improved and more tailored information, which is to be provided by specialised companies. All this will increase the know-how, the standing and well-being of European companies in the world market. In addition, those SMEs might provide researchers with their own preferences as to what is important to them and what is not. This is a point that is sometimes given inadequate attention by researchers and therefore needs to be reinforced. In addition, most research organisations in Europe have already established efficient means of creating spin-offs in the form of SMEs that will transfer existing research results into more exciting products .

The real benefits for competitiveness and SMEs, will only be realised if the interfaces with which the autonomous systems communicate are publicly available, thus reducing the barriers to entry into traffic monitoring and information provision markets by enabling additional systems to be created (for example systems that address key monitoring or information needs) which communicate simply with existing systems. Competitiveness may lead to improved services provided through harmonised communication between various autonomous systems, but there is a real risk that although the systems themselves are autonomous, unless the communication interfaces are open, the potential for the creation of added value systems will be greatly reduced. Small and medium sized enterprises may find direct and indirect opportunities to capture a significant place in the market through research on the communication between autonomous systems. Directly there could be many services provided by an SME or instances of management of an autonomous system that could be outsourced to an SME. There could also very well be introduction of innovative autonomous systems from scratch to complement existing systems beneficially in terms of gaps in existing data collection. Indirectly, SMEs may also attempt to improve the transport system in various ways by adding value to the better understanding enabled by improved co-operation of autonomous systems.

Both multi-scale traffic management and further developments in intelligent vehicles require many participating parties. In particular the co-operation between these parties, each with their own point of view and complementary skills will stimulate progress and scientific developments. In addition, activities at universities may result in spinoff companies to exploit their innovations. Europe is characterised by a large number of areas which may benefit from Multi Scale Traffic Management (MSTM). Pilot studies in one or more of these areas to show the benefits of MSTM will increase not only the scientific knowledge and insight into these management systems, but also the practical, technological and policy related knowledge on how such systems should be developed. In particular, ICT companies and system developers , service providers, and the traffic industry will benefit from the opportunities and innovations.

An efficient transport system, enabled *via* promising, targeted and practicable research and development, is potentially beneficial for European competitiveness in at least two ways: firstly, a mitigation of the current traffic congestion problems on European roads will improve efficiency and decrease costs for a vast portion of domestic enterprises; in addition, it will render Europe a more attractive place for investment and businesses that rely, by their nature, on the efficiency of the road transport system. Secondly, the achieved know-how, if appropriately channelled to innovative commercial products and services, will represent an advantage for European enterprises involved in the traffic management sector. This will increase the international status and competitiveness of the relevant industrial sectors and contribute to an increased deployment of European technology around the globe.

Europe arguably leads the world in the quality of its traffic management systems and their supporting Research and Development. Maintaining this competitive advantage cannot be taken for granted. Investment at the European level will be required continually to enhance and improve our traffic management systems, particularly in the directions recognised in the NEARCTIS research themes. This will benefit a range of industrial concerns and SMEs through the manufacturing and export potential generated by these leading-edge technical developments. It is clear that the transport problems being faced in Europe are also becoming increasingly common in other parts of the world, so the NEARCTIS recommendations for research and development are clearly consistent with the competitiveness aspirations set out for Europe in Horizon 2020. Advances in ICT are constantly opening new opportunities for the involvement of small and medium sized enterprises. Such an opportunity in the near future will undoubtedly be advances in Intelligent Transport Systems as we look to new solutions for transport problems. As already noted, in-vehicle systems, traffic management and co-operative systems will be key elements in these solutions.

5.3. Excellent science

The increased use of mobile communications will impact on Europe's science base positively in the field of transport, as it provides fertile land for a large family of needed technological innovations to be addressed by the European research community. This includes advanced methodological developments (*e.g.* mobile-probe-based traffic assignment algorithms), hardware-related improvements (*e.g.* tracking of mobile probes underground) and the creation of new products and services (*e.g.* real-time pedestrian navigation).

Strong focus on innovation is the main objective developed in the Horizon 2020programme. This leads to the reinforcement of scientific excellence and creativity. A better integration of education, research and innovation is certainly the most encouraging way for young researchers and for future entrepreneurs.

Access to information and high-quality databases are necessary conditions for improving the integration between science and education. The development of joint structures (science or technology hubs) between universities, start-up companies and research centres has proved that sharing resources (*e.g.* databases) is a route to success. It improves technology transfer and connects faster emerging developments with the market. Improved modelling, for all the four research areas described above, will obviously have significant impact on Europe's science base. All four areas contain tremendous scientific challenges that can only be mastered when many different approaches play together: better models, better numerical and computational concepts, and of course, since we are dealing with really large systems, performing distributed computing in the cloud or on large parallel machines. Succeeding in this endeavour will clearly prove Europe's excellence in performing applied as well as fundamental research. In addition, it will have an element of self-reinforcement as it will draw other researchers from around the world to join, to co-operate with and to emulate European research groups.

The communication between autonomous systems will identify potential needs and questions to be tackled by the European research community. Some of these needs and questions are related specifically to transport, whereas others (*e.g.* data fusion, information overload) are more generic but are ones where transport will provide substantial and economically important case studies.

To develop multi-scale traffic management, intelligent vehicles as well as interaction between intelligent vehicles and traffic management a lot of knowledge still needs to be developed. This knowledge includes both fundamental scientific knowledge related to the development of traffic management algorithms and practical or applied knowledge for the field studies and the functionalities of intelligent vehicles. As the task is large, it should not only bring together top European researchers, but also attract new researchers to accept this challenge, which will increase the scientific knowledge level in Europe, thus contributing to raising the level of excellence in Europe's science base and ensuring a steady stream of world-class research.

The value of this innovative research is not limited to the mitigation of the currently faced transport-related problems, but extends to a genuine broadening of the societal knowledge and capabilities to address potential future problems and needs, in some cases even beyond the original specific application areas; clearly, this calls for inter-disciplinary, generic and systematic research and development approaches, rather than local or individual problem-fixing procedures.

The accumulated knowledge and experience in traffic management issues over the last decades is vast. This knowledge must be fully exploited when addressing or designing a new generation of co-operative systems and management. Newcomers in the area of co-operative systems must be enlightened so that they become aware of this knowledge in order to avoid the possibility of awkward attempts to handle anew issues of traffic management that have a long-standing history of development and efficient solutions.

The development of effective co-operative traffic management systems proposed by NEARCTIS will be underpinned by fundamental scientific research in a number of areas, including traffic flow theory, data fusion, mobile communications and real-time control, to name a few. Europe has a leading academic and scientific capability in these areas, including the institutions represented in NEARCTIS for traffic management. EC investment in the research topics proposed by NEARCTIS will undoubtedly satisfy this key objective of Horizon 2020 thus strengthening Europe's science base.

6. Conclusions

The Harmonised Research Programmeon cooperative ICT in traffic management and control that was presented in deliverable D14 has substantial scope to contribute across the range of NEARCTIS objectives and Horizon 2020 priorities. Each of the research themes of the Harmonised Research Programme has a distinct profile of likely contributions. The systematic approach developed in the present deliverable explores these profiles by identifying the potential contributions of each of the research themes. A particular benefit of this is to identify which of the research themes is likely to contribute most to each of the objectives and priorities so that where specific requirements can be identified, research can be undertaken accordingly.

In this chapter, we summarise the likely contribution of each of the NEARCTIS research themes to the objectives of NEARCTIS and the priorities of Horizon 2020. The benefits and challenges relevant to each of the research themes in respect of the NEARCTIS objectives are presented in Table 6.1 and in respect of the Horizon 2020 priorities in Table 6.2.

6.1. Increased Availability of Mobile Communication

The increased availability of mobile communications will provide many opportunities for beneficial developments in cooperative ICT for transport. These technologies will be central to the transfer of data and information among users, between users and managers, and between system components. This will provide means to transmit and receive traffic information, ranging from short-term local to longer-term and network-wide.

Within the objective of NEARCTIS, this will provide opportunities to realise substantial benefits in safety through accident prevention and through mitigation of any that do occur. Improved communication will lead to benefits through improved monitoring of the state of transport systems and through improved delivery of management and control. Information about the state of the system will include current locations and speeds of vehicles in the traffic and also indications of travel intentions of current and future travellers. This will be beneficial in managing operations under normal and under incident conditions.

6.2. Increased Data Availability

This theme of research will be supporting fully integrated topics from fundamental concepts to the implementation of models. Thinking about interoperability from the early stage of a new development is a key aspect for a better integration of complex models, especially in relation to the environment. The main benefits of this research theme are: the availability of innovative data models, metadata and mechanisms for the exchange of data; the development of tools for the assessment of data quality which will allow the deployment of liability or safety-critical applications; a better interoperability of applications with a particular focus on cooperative multimodal management; the development of a smart data-warehouse gathering multiple sources of data in a consistent and effective manner.

This research theme has also some identified drawbacks: the indirect costs induced by the increased time necessary for the management and processing of huge amount of data; the difficulty of defining the boundary between public data and private data which can have a deep impact on privacy issues; data models becoming increasingly complex, which will not facilitate universal access to data (and may thus lead to risk of monopoly by major service providers).

6.3. Improved Modelling at all Scales

There is a large degree of coherence among the research topics as well as between the objectives of NEARCTIS and the priorities of Horizon 2020. It can be expected that improvements in modelling will lead to better analysis and quantification of the NEARCTIS objectives. This will then support monitoring, management and control in transport systems that more closely addresses and promotes these objectives, and through this aligns with the priorities of Horizon 2020. This will bring benefits regarding not only transport and environmental issues but also societal, innovation and competitiveness ones.

6.4. The Need for Communication Between Autonomous Systems

Research under this theme will lead to a fuller understanding of the operation of complex systems that include multiple autonomous systems. This will lead to was in which performance of traffic management systems can be harmonised through communication between autonomous systems. The benefit of this will accrue in relation to the objectives of NEARCTIS and the Horizon 2020priorities. For this research theme, the most relevant NEARCTIS objectives are the efficiency of the transport system, safety and traveller experience. Particularly for the safety objective, through the improved cooperation, the capability of incident detection and response will be significantly improved and therefore benefit safety directly.

For the Horizon 2020 priorities, societal challenges and competitiveness are the most promising areas associated with the various autonomous systems research areas, but it is recognised that openness within the communications interfaces will be a key determinant of success. While this research theme is predominantly an enabler for downstream applications, its success facilitates many potential applications leading to benefits across all the NEARCTIS objectives and the Horizon 2020 priorities.

6.5. Understanding Interactions at Various Levels

The research theme on understanding interaction at various levels is characterised by research with three different levels of interaction between autonomous intelligent vehicles and (multi-scale) traffic management systems. Improvements are expected in more efficient driving leading to higher capacities of individual roads, to distribution of congestion over larger areas thus not only reducing delays, travel time variability, fuel consumption and emissions, but also distributing nuisance caused by the traffic system as a whole more equally, and to improved safety. Drawbacks are found in the equity of the system: intelligent vehicles come at a price that is not affordable for everybody, and distributing traffic over a network implies making choices about which drivers will experience how much delay. In addition, intelligent vehicles and other systems supporting driving behaviour require a large change in driver attitude and may reduce drivers' freedom to make choices. However, the benefits, not only for the traffic system as a whole but also for individual drivers seem likely to outweigh these drawbacks. With respect to the Horizon 2020 priorities, the various research themes appear to have in general a positive effect.

6.6. Achieving effective large-scale transport systems and their efficient usage

This NEARCTIS research theme comprises several core areas of cooperative traffic management developments that offer the prospect of significantly improving the performance of current road transport systems. Improvements are expected in the space-time extent of congestion (and the resulting journey times), in the environmental impact of road transport, and in traffic safety. These improvements are expected to reduce significantly the societal resources that are wasted in traffic congestion. A successful outcome of the research proposed by NEARCTIS will also reinforce the top ranking of European research in the area of cooperative traffic management and will contribute to an increased competitiveness of European businesses in the transport sector and beyond.

The evaluation criteria of NEARCTIS may in some circumstances be partially contradicting; although appreciable improvements are within reach for all objectives, some appropriate trade-offs will be necessary in specific cases. Traveller behaviour in terms of mode choice should also be an issue of analysis and investigation towards a globally optimal transport system. Equity considerations and constraints for individual groups of road users (or non-users) must be observed, so as to advance towards an efficient, but also fair service provision for all citizens. User acceptance and convenience is another prerequisite for effective traffic management. Appropriate training actions must ensure that the accumulated knowledge in the domain is preserved and exploited, not re-invented. Last but not least, the appropriate amount of funding should be reserved for the area of traffic management to enable and achieve a globally beneficial impact of significant technological advances to reinforce the European excellence in the domain.

6.7. Support for policy developers, decision makers, managers and operators

The potential benefits of cooperative traffic management will require appropriate and relevant legislation and policies to be implemented. For this to happen, policy developers and decision makers will need to be properly informed and advised. Awareness of opportunities for application, the scope of technological development and capability, and the specific nature of benefits from implementation all form important elements of this support.

It is concluded that the different categories of researchers responsible for system choice, design and deployment will have different requirements to fulfil. For example:

- Policymakers need evidence on the benefits of co-operative traffic management in general to support their policies on this topic.
- Decision-makers need advice on which co-operative traffic management applications to pursue. This requires (1) evidence of effectiveness of these applications, bearing in mind the stated policies (European, national, local) and (2) advice on how these applications should be evaluated.
- Managers need to know how to implement the selected applications most effectively in an integrated way. This requires advice on optimisation.
- Operators need clear guidelines for the effective day-to-day operation and maintenance of the applications they control.

Guidelines on pre-implementation evaluation methods will be essential. These may vary from analytical and mathematical studies, through microscopic simulation studies to full-scale dynamic network assignment models or their equivalent. The key will be to choose the evaluation method that is most appropriate to the application being evaluated, based on its characteristics and expected effects and to recognise the limitations of the method. It is also necessary to identify the effects and objectives to be evaluated, and the evaluation methods appropriate for each such combination. Methods are already generally available for evaluating against each of the NEARCTIS objectives and Horizon 2020 priorities, but some are more developed than others, implying the need for further research on certain specific methods for systems evaluation.

6.8. Summary

In summary, we can identify many likely contributions of research activity undertaken according to each of the research themes that were identified in NEARCTIS deliverable D14. This includes a range ways in which research under each of the themes will contribute. In some cases, the research is required to facilitate other activities that will in turn yield benefit to the community. The range of benefits that are likely ultimately to arise from this work is wide, including those travelling, those providing and managing travel facilities, and the community more generally. Several specific objectives of these kinds have been identified as part of the NEARCTIS endeavour. Beyond this, a range of priorities have been specified for the forthcoming Horizon 2020 programme to which the Harmonised Research Programme will contribute in a range of ways. Taken together, this shows the substantial benefit that is likely to result from following the Harmonised Research Programme.

NEARCTIS research theme	Benefits	Challenges
Increased use of mobile communication	Accident prevention Short term traffic information Lower fuel consumption and pollutant emissions Advanced traveller information Access to personalised mobility information	Indirect promotion of use of mobile phones while driving Wider use may require more energy Natural resources for manufacturing Social exclusion for technologically deprived Cost of technology for users
Data Availability	More and better data available for analysis and model development Better understanding of data quality Range of appropriate data available	Privacy concerns on inappropriate use of personal data Requires management and processing resources
Improved Modelling	Improved understanding of traffic behaviour More reliable estimates Better models for management Better estimates of emissions	Effective use of available data Facilitating transfer between models Excessive reliance on model predictions Inappropriate responses to models
Autonomous Systems	Improved incident detection and response Improved routing advice especially after incidents	Over-reliance on communications leading to fragile systems Excessive communication leading to bandwidth and latency problems
Understanding Interactions	Vehicle to vehicle communication to improve safety Support for driving response to traffic conditions Traffic controllers responsive to traffic conditions elsewhere	Avoiding disruptive feedback effects Need for public takeup of communicating vehicles
Large Scale management	Faster incident handling Better management of environmental impacts Lower fuel consumption and pollutant emissions	Implementation results in over-reliance on technology Need for better risk estimates Problems of equity for management measures Focus only on applications and not on theory
Support for policy makers	Tools for evaluation of proposed measures Better understanding of the safety and environmental impacts Improved cost-benefit analysis	Ensuring tools are easily usable by intended targets Ensuring information is presented in useful and helpful forms Ensuring the limitations are understood

Table 6.1: Summary of benefits and challenges of the Harmonised Research Programme for NEARCTIS objectives

NEARCTIS research theme	Benefits	Challenges
Increased use of mobile communication	Better data about emissions *etc* Contributes to a better, greener traffic management Openings for suppliers of equipment and services (*c.f.* SafeTRIP www.safetrip.eu) More scope for research on traffic assignment algorithms	Intrusion into personal data Some residents will lose from the reshuffling of traffic Monopolies could emerge and SMEs could end up excluded Focus only on applications and not on theory
Data Availability	Encouraging inter-disciplinary research and cooperation Opportunities to develop new services	Ensuring data is easily accessible *via* data repositories Avoiding data hoarding Ensuring effective use of the data
Improved Modelling	Improved control of emissions Integration of models into products of SMEs Enhanced scientific leadership	
Autonomous Systems	Contributions to safer, greener more integrated transport systems Open system specifications encourages innovation Encouragement of modal choice and switching	Concerns over confidentiality and use of personal data
Understanding Interactions	Reduced congestion and smoother traffic flow Opportunities for SMEs	
Large Scale management	Entry of large number of suppliers in the market Research on traffic assignment algorithms and other aspects of traffic modelling enhances European leadership	Intrusive use of personal data Ensuring consistent traffic information and advice Some residents will lose from traffic rearrangement Monopolies could emerge and SMEs could end up excluded
Support for policy makers	Wider take up and implementation of beneficial traffic management policies Opportunities to export policy making and design expertise	Tools, data use need to integrate into the policy formulation and decision making processes Investment needed

Table 6.2: Summary of benefits and challenges of the Harmonised Research Programme for Horizon 2020 priorities