Grant agreement no: 224272
Start date: 01/07/2008
http://www.nearctis.org

The Harmonised Research Programme

D14: Executive Summary

Confidentiality level: public

Deliverable 2 of work package 1
Status: draft
Date 11/03/2012
Edited by: UCL

Authors

Name	Institution
BG Heydecker	UCL
J D Addison	UCL

Amendments

Date of Issue	Description
November 22, 2011	Initial Draft
December 28, 2011	Final Draft
January 16, 2012	Initial Revision

Applicable Documents

Description
NEARCTIS deliverable D14:The Harmonised Research Programme

Acknowledgements

Description

Executive Summary

Introduction

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 prospect of continuation of this trend presents opportunities for innovative research and solutions. In this context, the emergence of new objectives, new methods and new constraints give rise to opportunities for development and improvement. In order to anticipate and harness these advances for traffic management and control, a switch will be required from opportunistic exploitation of technological innovation to an approach to research that addresses these challenges in a planned and systematic way. The present document provides a rationale for and formulation of a harmonised research programme for this.

Traffic management has moved from an isolated technical problem to a more integrated vision of widespread mobility in which multiple criteria and constraints have to be taken into account, and with demand management being increasingly necessary to combat congestion. At the same time, technology has been developing rapidly, with various new methods now available to communicate information to road users. Related developments include new means to collect, integrate and use this information, including vehicle positioning, identification and tracking, and bi-directional communication technologies. Methodologies have also been improved: advanced traffic measurement techniques have made high quality traffic data available that can be used in support of traffic models and analysis, and optimisation techniques have also been improved. This has made it possible to improve the spatial and temporal resolution of analysis for traffic modelling and optimisation, and so to take a better account of each vehicle or platoon. This opens up a wide area for research and development to take full advantage of the opportunities for improvements that can be achieved through cooperative ICT.

There is an overarching need for cost-effective, efficient transport systems that provide a wide range of attractive choices to all members of society. Various objectives of traffic management have been addressed to different degrees by large research programmes on technological aspects, involving researchers and industrialists working together. However, it is now clear that improvements cannot be based only on technological components but must integrate them into a more global vision for planning, organisation, management, operation and optimisation of the transport system.

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 exploration and development in respect of those ways in which the transport system can be improved through adoption and use of cooperative ICT. One of the main objectives is to develop a harmonised research programme on cooperative traffic management, based upon 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. This has been synthesised in the present deliverable D14.

Communication and cooperation for transport systems management

A key element underlying the development of ICT for cooperative traffic management is communication. The emergent technology of dedicated short range communication (DSRC) to facilitate communication among vehicles and bi-directional communication between vehicles and infrastructure is especially relevant for this. The different kinds of communication can therefore be described as

Vehicle –> vehicle
Vehicle –> infrastructure
Infrastructure -> vehicle
Bi-directional vehicle <-> infrastructure.

Safety-related ITS applications will be the first priority in harmonisation and deployment on both "intelligent" segments: the vehicle (connected and networked) and the road infrastructure (road operators, traffic managers, services providers). In this context, these future very demanding applications will require high level traffic models, efficient and reliable communication tools, and accurate measuring and monitoring systems. The role of technologies, in particular communication and positioning, will be essential in the enhancement of the traffic management.

The NEARCTIS consortium believes that for future cooperative traffic management systems to succeed, high quality positioning, tracking and communications (PTC) technologies will be essential to provide accurate positioning and secure communications with associated estimates of quality parameters (positioning accuracy, integrity, availability, ...)

Communication between vehicles and infrastructure is at the heart of cooperative systems. In order to help show how it has the potential to contribute to traffic management we have developed a simple taxonomy of communication and cooperation that we present here in terms of the two roles of User and System, with three modes of communication and cooperation between them that can combine to produce complex interactions:

1. User <--> User
2. User <--> System
3. System <--> System

The recent technological evolution of V2V (vehicle to vehicle) and V2I (vehicle to infrastructure) communication tools opens the prospect of information being exchanged between vehicles, or ascending from vehicle to system or descending from system to vehicles, and thus of devising traffic management systems based on these new capabilities.

The growing interest in the applications of ideas from physics to social sciences and complexity issues has led to convergence between new technological means and new conceptual frameworks. This has promoted the idea of cooperative systems in transport systems with many agents (vehicles, controllers, authorities) interacting towards an improved and more efficient management of the system. The consequent requirement on traffic models is that they be adapted and developed in accordance with this new perspective.

Frame of reference

The harmonised research programme on cooperative ICT in transport is presented here within a framework that has 5 distinct dimensions. These are:

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

These five dimensions give complementary and cross-cutting views of the research. The concept of this is that each prospective piece of research in the harmonised programme can be viewed with reference to these 5 dimensions of classification, which will make explicit the inherent commonalities and the complementarities.

The definition of the harmonised research programme is a fundamental task for the NEARCTIS project. Accordingly, a systematic approach and methodology for the development of this was developed and adopted with the intention to ensure that the final research programme has the important characteristics that it be *robust*, *extensive*, *shared* and *balanced*. It should make full use of the available knowledge and technologies, but, at the same time, be open to future ones. This involved planning and undertaking a series of consultations of members of NEARCTIS consortium, each building on the results of the previous one. This approach to consultation was repeated four times during the development of the research programme. The first and second times supported consolidation of the 5-dimensional framework for the research agenda, leading to a shared agreement on each classification dimension and defining every subtopic. The first consultation established the key objectives and areas of expertise, whilst the second consultation confirmed the thematic view of future challenges identified by members of the consortium. The third consultation provided the necessary information to populate the framework and to synthesise the harmonised research programme. The final consultation reviewed the populated framework through the device of a round-table meeting with representatives from all the partners has provided the possibility to allow for flexible and dynamic discussion on the proposed research programme.

In order to explore the relationships among the activities and contributions within the research programme, a framework with 5 dimensions of classification was developed. These 5 dimensions are as follows.

Objectives of cooperative ICT

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. This led to identification of the following five **key objectives** of research on cooperative 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. Because the general consensus is that safety is of particular importance, there is agreement that innovations and interventions should be considered provided that they are at least safety-neutral. Further objectives included within these include accessibility, economic return, livability and sustainability.

Research themes

The fundamental classification of opportunities to develop cooperative ICT for transport leads to a thematic view of future challenges to be addressed. Each of the emergent themes represents a way in which appropriate research can be oriented and focused according to the following 7 broad themes.

1. Increased availability of mobile communication
2. Increasing data availability
3. Improved modelling at all scales

4. The need for communication between autonomous systems
5. An understanding of these 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 harmonised research programme is described considering each of these themes in turn.

Areas of expertise

Leading research in the area of cooperative ICT in transport will call on high levels of knowledge, understanding, capability and skills in each of analysis, engineering and social science. The effectiveness of cooperative systems will depend on an understanding of travellers' and other users' behaviour and their responses to increasing information and more flexible systems. The particular areas of expertise that are identified as being directly relevant and so to contribute to research on cooperative ICT are described below. Strong capabilities in these areas will be required to contribute to the research initiatives and technological developments that are envisaged within the research programme. These will be complemented by other knowledge and expertise, including that from practical implementation, industrial capabilities for manufacturing, planning and operation.

Traffic modelling for cooperative systems integration
The varying role and use of models can be identified as including the key areas of: understanding the system, controlling the system, evaluation, transport planning, and infrastructure planning. Three particular varieties of these systems can be identified as: cooperative individual agents (corresponding to driver/vehicle units), cooperative controllers, and integrated cooperative systems (associating vehicles and controllers).

Optimisation and Control
The efficient, safe transport of persons and goods with minimal pollution calls for optimal management and use of the available infrastructure via suitable application of a variety of traffic control measures. This trend is facilitated by the rapid developments in the areas of communications and computing (telematics), but it is evident that the efficiency of traffic control depends directly on the efficiency and relevance of the control methodologies that are employed.

Positioning, tracking and communication
The deployment of future traffic management services will be supported by the development of new technologies of communications and positioning. In the context of road safety, future applications will require accurate measuring and monitoring systems as well as high quality traffic models, and efficient and reliable communication tools.

Impact assessment, deployment and implementation
Four areas relevant to successful implementation and deployment of ITS applications are: impact assessment, system architecture, interoperability and transition effects, and uncertainty and robustness. With the use of detailed simulation models, significant impact assessment for some indicators such as travel time, travel time variability, fuel consumption, emissions, vehicle speed, and traffic conflicts becomes possible. These advances in system architecture will lead to increased reliability, capability, and efficiency of different cooperative systems. Last, for the issues of uncertainty and robustness, achievements are revealed in the applications to traffic measurement, travel time prediction and incident detection with increased detection rate and reduced false alarm rate.

Evaluation
The aim of NEARCTIS is to improve the long-term performance of the transport system by the use of ICT for the deployment of cooperative traffic management. Contributions will be required in the three key areas of: the formulation and evaluation of policy objectives, identifying appropriate traffic management techniques as potential contributors to these objectives, and developing effective tools to design and evaluate these measures. The knowledge required for the evaluation task differs from that for the other tasks in this work package. Four distinct areas that need to be considered and understood for evaluation are: the users and stakeholders, including providers, managers and users of the transport system, and their interests; the role of technologies and research activities in progressing effective integrated transport systems through cooperative deployment; techniques and methods for identifying and evaluating the available technologies for achieving identified ends; and assessment of the performance of the transport system. Focus should be restricted to areas that are relevant to the particular instances of cooperative traffic management that are the subject of the research being evaluated.

This fifth task, Evaluation, is a cross-cutting task aimed at evaluating and identifying the benefits that will arise from the final research programme. The work of this task is formulate a common view of how and against what criteria the research programme should be evaluated to show that it will contribute successfully to achieving the goals of the NEARCTIS project. (This will be explored more fully in D18)

Traffic management applications

This dimension of the 5-dimensional frame work identifies areas of traffic management according to the role the play in the management of the transport system as a whole. The taxonomy used here follows that of D7 and D8. The areas of traffic management (TM) where research in the future programme could contribute are as follows

Global services
The state-of-the-art of global service implementation on advanced traffic management, with respect to shadow toll systems, fleet management, door-to-door travel support and individual cooperative systems were identified. Besides, the impacts on mobility, safety, environment, and

user acceptance of GPS implementations were evaluated. It was revealed that the enhancement of interoperability with well-coordinated framework is critical to the success of future applications on international level.

Large highway corridors
Traffic management methods for large highway corridors include driver information systems, route guidance, local and coordinated ramp metering, variable speed limits, vehicle-to-vehicle and vehicle-to-infrastructure communications, tunnel management, and traffic surveillance. While application of each of these has reported measurable benefits, it is seen that further enhancements are possible. The efficient, safe, and less polluting transport of persons and goods calls for optimal use of the available infrastructure via suitable application of a variety of traffic control measures. Daily varying demands, changing environmental conditions, exceptional events and incidents may change the typical daily traffic conditions in an unpredictable way. Route guidance and driver information systems may be employed to improve the network efficiency via travel-time displays or direct recommendation of alternative routes.

Dense urban networks
Case studies show that advanced ITS systems have been implemented in several European dense urban networks. These covered the topics of urban traffic control, congestion management, traffic information collection and provision, congestion charging and public transport priority. Further advanced implementations exist world-wide. Analysis of these case studies shows that traffic management applications in these areas could benefit from more effective cooperative systems.

Local main road networks
Management here is concerned on one hand with managed lanes operations and on the other hand with incident management on road local networks. Various practices are implemented including additional lanes, hard shoulder running, high occupancy vehicle (HOV) and reserved lanes. The development of suitable cooperative systems would have a beneficial impact on managed lane operations.

Multi-modal networks
Multi-modal management applications are primarily concerned to promote sustainable transport by encouraging wider use of a range of means of transport. This includes potential priorities to those modes that support the movement of people rather than vehicles. Advanced applications of this kind have a significant ITS (Intelligent Transport Systems) component, particularly regarding the need for road user detection, communications and advanced control strategies.

Opportunities for innovative contribution

The four **technical opportunities** for innovative contribution by cooperative ICT are:

1. Evolving methodologies
2. Emerging technologies (sensors, communications)
3. Enhanced traffic management applications
4. Novel traffic management approaches.

Applications of combinations of these opportunities to address traffic management needs and requirements are considered to be most appropriate where improvements can be made to one or other of efficiency, effectiveness or scope of traffic management. On the other hand, where a traffic management activity is currently undertaken adequately and development of cooperative ICT applications does not stand to improve any of these, then research into this activity this should not be a high priority.

The Harmonised Research Programme

We propose a harmonised programme of research in the form of a thematic agenda. This is organised according to the seven research themes that were introduced as part of the framework. We discuss the nature and interpretation of each of these themes and synthesise the relevant contributions. Within each theme, we introduce research areas that were identified by considering and building upon contributions from partners. For each of these areas, we address each of the motivation for researching this area, the premises on which the research is based, and the research that will be required, including some of the major issues to be addressed. We then proceed to discuss the expected outcomes of researching that theme.

This thematic presentation of a research agenda is intended to form the basis of a harmonised programme of research. This programme identifies some of the areas of research to be addressed in order to develop and exploit the potential benefits of cooperative ICT for traffic management. The agenda as presented here is intended to be extensive and includes a wide range of topics but still remains open to extension and enrichment from complementary research ideas. The programme therefore includes scope for many projects, each with specific objectives.

Increased availability of mobile communications
The increasing ease of use and availability of mobile communications offers the prospect of making available data on current and likely short-term future traffic, road and weather conditions. There is also the prospect of providing information of this kind to vehicles upstream so that appropriate decisions and actions can be taken by managers and travellers. This increased availability of mobile communications will play an important role in the development of cooperative traffic management.

The capture of data by operators through making measurements from transport operations and the extraction of information from that can be used to facilitate its effective management. This can include macroscopic measurements of quantities that correspond to usage such as mean speed, flow and density of traffic. Measurements of usage can also include microscopic measurements of individual positions, speeds and travel times achieved. Other measurements can be made to monitor performance of the infrastructure to achieve good operation and control, and rapid detection and effective management of any incidents that affect this. The information extracted from this can be used to monitor transport networks and to support control and management of traffic operations. The second class of recipient is the users, so we also consider transmission of data and information to them. This can be used in various ways to inform, manage and control traffic and network operations.

The increased availability of mobile communications will play a central role in realising ICT in traffic management and control and hence in implementing cooperative systems as envisaged here. Mobile communications will provide the means for vehicle to vehicle and vehicle to infrastructure communication, and hence will be required to implement systems involving vehicles that cooperate in real time. Measurements made from vehicles can be communicated to infrastructure-based systems for use in real time. This will result in better quality of management and control in normal conditions, and will facilitate rapid detection and response to incidents. Information generated by control systems can be disseminated directly to vehicles using mobile communications. This can either be common information broadcast to all users or information targeted to individuals according to their usage and profile. Traveller information can also be sourced directly from other travellers and communicated directly.

The effects of this mobile communication will be greater levels of information for system operators and for users. For the system, this will be beneficial in achieving more effective monitoring, and better quality of control and management of road networks. For users, this will be beneficial in providing greater levels of information and so supporting better choices in using the transport system safely and effectively.

Increasing data availability
A consequence of increased mobile communication is that as well as a providing a means of delivering information, it also provides an extensive source of data. This will relate to the current traffic and system states, and beyond this to actions to which travellers and vehicles are committed and on the travel intentions that underlie choices and behaviour. In several cases, these sources can be used to provide data about plans and intentions as well as current state. Information of this kind can be used to anticipate developments of the system and hence to lead to better dynamic modelling and management.

The issues that will require research in this include data quality, collection and fusion of diverse and heterogeneous data, and appropriate statistical processing and analysis of data. The increased availability of data resulting from use of novel measurement systems and techniques will enrich and enhance traffic management and control. Measurement of traditional quantities can be improved in accuracy, can be enhanced by fusion with other data, and can be expanded in scope and scale. Use of this improved data will result in more accurately calculated control measures and so will enhance system operation and efficiency. Quantities will also become available that have not been measured in the past. These will include some that reveal travellers' intentions in a way that informs beyond the current state of traffic on the network. Use of information of this kind will enable systems to anticipate future developments in traffic more accurately and hence to calculate more appropriate control and management measures.

Improved modelling at all scales
The availability of detailed data about traffic conditions will offer new opportunities and challenges for modelling at all scales. For use with cooperative systems, ease of transfer of results between models will become increasingly important. Large-scale availability of diverse real-time data will offer new modelling opportunities at the small scale to assess the likely development from current traffic conditions, and the impact and consequences of incidents and of traffic management measures. At the other extreme, modelling on a larger, even regional, scale will be required to understand fully the operation and effects of autonomous but cooperative traffic management systems.

The issues that will require research in this include real-time estimation of traffic conditions, improving estimation of travel time and other performance measures, dynamic modelling of travel behaviour, and developing microscopic traffic flow models to address safety issues.

Improved modelling of traffic and operation of transport systems will lead to more accurate calculation of control measures for the prevailing and likely future conditions. Combined use of observed data with anticipative models can be used within filtering frameworks to improve the quality of estimates of traffic conditions and system state in real time. This in turn will support monitoring and control functions for management of the network, including the estimation of measures of performance. Dynamic transport models, which are required for congested conditions because they are necessarily transient, will become more practical and more applicable as more and better sources of timely data become available through enhanced ICT. This will lead to better management of networks in congested conditions. Improvements to microscopic traffic models in respect of their representation of safety-critical behaviour will improve understanding of circumstances that contribute to crashes, and hence will lead to improvements in design and operation for safety.

The need for communication between autonomous systems
Effective cooperation will require timely communication of high quality reliable traffic and other data. It will also include of traffic management and other related objectives and decisions. Work will be needed to identify appropriate information to transmit, and to develop standards for its communication and interpretation.

Several means will be available in the near future for communication of this kind. These include direct bi-directional use of dedicated short-range communication (DSRC) among vehicles, potentially up to a range of about 1km according to specific requirements. Communication among vehicles in the fleet can be facilitated by channels through infrastructure, including DSRC links from vehicles to infrastructure for uplink and infrastructure to vehicles for downlink. In cases where the communication is between one or more individual users and elements of the transport system, this can be provided by DSRC and can also be provided by asymmetric communications using satellite-based systems. The advantages of satellite include high broadcast bandwidth and wide area coverage for the downlink; the limitations include that broadcast communications *via* the downlink are undifferentiated, that uplink bandwidth is limited, and that connectivity depends on clear-sky views or provision of a proxy.

The issues that will require research in this include cooperative strategies for fleet management, and mutually supportive operation of management methods.

Communications between autonomous systems is an essential component of cooperation. This will include sharing of current data and information on system states, which will be available to each system component in the course of its normal operation. Sharing information of this kind will ensure that best use can be made of data that have been measured throughout the transport system. Beyond this, mutual information control and management actions will be beneficial for coordination and cooperation between autonomous systems. In cases where decisions can be made jointly by distinct system components, this will provide opportunities to enhance performance beyond what can be achieved by isolated autonomous action. Communication of objectives and intentions of different systems will enable others to anticipate likely responses and so to adjust control actions accordingly in order to enhance performance.

An understanding of the consequences of interactions at various levels
Cooperative interaction can take place at many levels. Because the communicating systems are autonomous the collective results of their independent decisions can be complex. Understanding the mechanisms of interaction, their potential benefits and the possible consequences that arise from this cooperation will be essential in order to achieve mechanisms of cooperation are required that lead to coherent and desirable combined behaviour.

The issues that will require research in this include intelligent vehicles, multi-scale traffic control, and understanding interactions among active systems. This will be important in achieving stable and acceptable operation. In systems with multiple actors, the data for one can correspond to the decision variables of another. If this is not managed, the possible consequences include poor operation, poor performance and poor stability, to the disadvantage of users and managers. On the other hand, if the kind and nature of interactions among system components are understood adequately, then the collective system can be managed effectively and performance enhanced. This will entail decisions that are modified in light of an understanding of the effects that they will have indirectly through interaction with other system components.

Achieving effective large-scale management of transport systems and their efficient usage
This theme is at the heart of much of the anticipated benefits of cooperative transport management. There are requirements to address the challenges of large-scale management, to identify the tools needed to make this effective, and to address the issues of integration. Rather than acting locally to anticipate problems and deal with local traffic and transport issues, management systems will be better able to consider the wider effects of local decisions and make their own decisions on the basis of better information about future anticipated traffic conditions

The research identified here can contribute synergetically to the achievement of effective cooperative transport management. In order to do this the challenges of large-scale management must be addressed, the tools needed to make this effective identified, and the issues of integration addressed.

The issues that will require research in this include incident management, pedestrians in the multi-modal environment, active management of motorway traffic, urban traffic control, responsive and adaptive optimisation, safety on rural roads, and differential road pricing.

The benefits of achieving more effective transport systems will be that a greater provision of transport will be possible with a given practical level of resource input. This will promote the more economic provision of transport to achieve greater mobility and reduced impact without increasing resourced cost. The benefits of achieving more efficient usage of the transport system include that users will be able to satisfy their own travel requirements at reduced resource costs and impact on others. These improvements will be achieved by matching provision of transport systems to users' needs for transport and managing their operation better through use of better and more timely information.

Support for policy developers and decision makers
Effective realisation of the concept 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. Policy developers will need tools to facilitate evaluation of possibilities, identification of the range of possible benefits, and ultimately quantification of them.

The issues that will require research in this include designing shared spaces for pedestrians, and urban traffic control (UTC) and urban traffic management.

By providing support for policy developers, decision makers, managers and operators, cooperative ICT systems can enhanced transport provision on timescales ranging from short-term operational ones to long-term planning ones that influence future choices of location and hence demands for travel. Support of this kind will include identification of the range of measures that are appropriate for certain specified circumstances, through descriptions of the outcomes of their use in the past to estimates of likely performance in the present case. Support that is based on evidence and reasoned analysis can be used to generate a critical analysis of proposals and hence to support current professional choices.

Conclusions

The approach presented here explores the relevance of cooperative ICT to traffic management and control. The framework developed for this helps to identify ways in which contributions can be made. This has led to formulation of an agenda for research that will be required to develop and exploit the opportunities for advances in traffic management that are furnished by ICT. By taking this analytical approach, we are able to achieve some perspective on future opportunities and identify the actions that will be required to realise them.

Considering in turn each of various research themes led to the formulation of a programme of research across 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. It also supports the research effort by identifying the complementarities that will enhance the value of each contribution.

The broad base of expertise within the NEARCTIS consortium leads us to suppose that many of the main topics and issues have been identified in the harmonised research programme. Each research project and activity that addresses the programme will, in our view, address one or more of the many combinations of descriptions within the framework that has been developed. We do not expect that research coverage will be uniform across all these possible combinations. Some combinations that are central to the endeavour seem likely to appear in several projects, possibly with distinct treatments according to their linkage with others. By contrast, other combinations by their nature might rightly not be addressed in any project.

Because of their relevant expertise and established research interest in this field, we expect that partners of the NEARCTIS consortium will join in bids for research following any call of the kind proposed here. This will be based on areas where established strengths and interests can contribute to the research effort. Joint research activity of this kind will have the effect of perpetuating the NEARCTIS network through collaborative research contributions.