

A nighttime photograph of a cityscape. In the foreground, a multi-lane highway with light trails from moving vehicles. In the background, several modern buildings are illuminated, with one large curved building being particularly prominent. The sky is a deep blue.

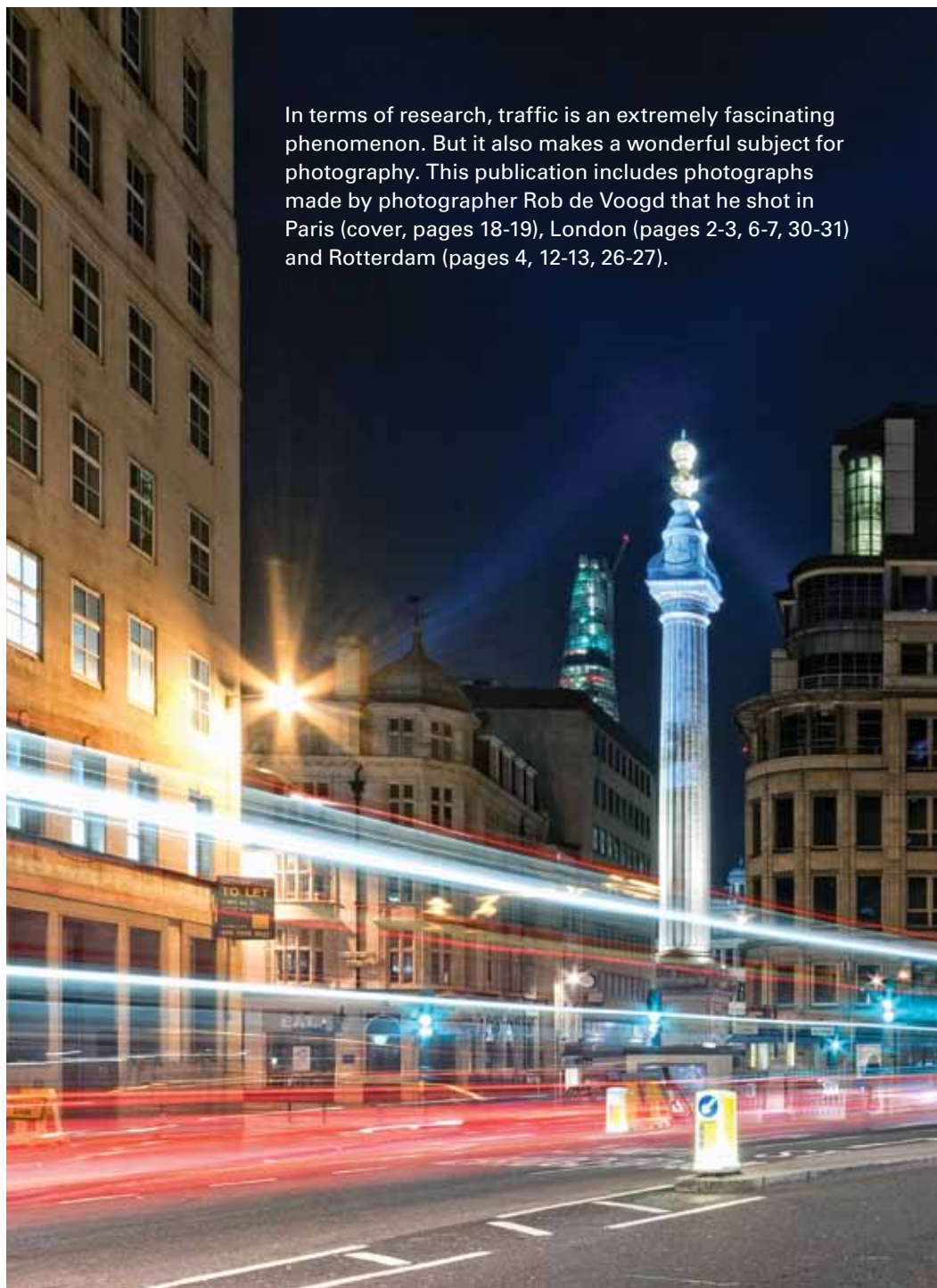
The NEARCTIS project

Network of Excellence
for Cooperative
Traffic Management

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In terms of research, traffic is an extremely fascinating phenomenon. But it also makes a wonderful subject for photography. This publication includes photographs made by photographer Rob de Voogd that he shot in Paris (cover, pages 18-19), London (pages 2-3, 6-7, 30-31) and Rotterdam (pages 4, 12-13, 26-27).





A photograph of a city street at dusk. On the left, a large, ornate building with a prominent clock tower and multiple domes is visible. The street is wet, reflecting the lights of cars and street lamps. Several cars are driving on the road, with their taillights glowing. On the right, there are bare trees and a sidewalk with a yellow and black striped crosswalk. The word "Contents" is overlaid in the center in a large, white, serif font, underlined.

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Foreword

What NEARCTIS is (And why we started it)

NEARCTIS, an EU-funded project founded in Brussels in July 2008, is an acronym for *Network of Excellence for Advanced Road Cooperative Traffic management in the Information Society*. Although quite a mouthful, the name is actually an apt description of NEARCTIS: a network of prominent academic research groups in the EU working on traffic control, management and optimisation with a particular focus on emerging co-operative systems.

NEARCTIS is funded under the 7th Research Framework Programme of the European Commission. There is good reason for this EU assistance. The promises offered by cooperative traffic systems that integrate intelligent cars, roadside systems and traffic control centres are tempting indeed: less congestion, improved safety, reduced fuel consumption, less air pollution. Yet even in a fully cooperative environment, traffic management will still be needed. What would such a management layer look like? Which traffic control tasks could be implemented by intelligent cars and when would supervision and intervention be necessary? How can high-tech traffic management *reinforce* the promises of cooperative traffic systems instead of *limiting* them? And how can we ensure that intelligent cars are managed in the same way throughout Europe? If we want co-operative systems to live up to their promises, we have to find solid answers to these questions.

This is why those of us at NEARCTIS drew up the following three objectives. First, we wanted to develop a common research agenda in the field of cooperative traffic control and management that addresses these research questions. Second, we wanted to organise the dissemination of the wide body of knowledge already available and to do this not just by

issuing reports but also by educating the thought leaders of tomorrow. Third, we wanted to lay the foundation for a European virtual centre of excellence in cooperative traffic control and management that would serve as an independent knowledge institute and liaison for this important topic in the development of the Horizon 2020 programme.

Now, five years later, support from the 7th Research Framework Programme is coming to an end. What has been achieved? Has NEARCTIS realised its objectives? This brochure, published especially for the final conference of NEARCTIS in Dublin, answers these questions. In line with the spirit of our objectives, we begin by 'disseminating knowledge': we once again provide a thorough explanation of why traffic management is necessary, even within a cooperative system. Next, we provide a brief overview of the results of five years of EU teamwork within our network of excellence. And, finally, we look ahead: what next, now that the NEARCTIS project has officially ended?

Needless to say, this brochure provides only the general outlines. All the underlying reports are available at www.nearctis.org. But the fact that we have made the effort to issue this document that includes a summary of the reports is an indication that we are proud of the results. The cooperation among the nine core members of NEARCTIS and the forty associated partners both inside and outside of the EU was so successful that it really should be followed up. NEARCTIS has ended, but its network of excellence is still very much alive!

The NEARCTIS Core Team

The partners in NEARCTIS

NEARCTIS contained a core team of nine prominent EU research groups that have been collaborating in the development of a common vision and research agenda for our field and have been engaging in sharing knowledge, research tools and resources. They

also joined forces to educate the traffic management researchers and practitioners of the future. Contributing to these activities was a group of forty associated partners active in the research and application of traffic management within and outside of the EU.

Core team



Delft University of Technology
(The Netherlands)



Institut Français des Sciences et
Technologies des Transport, de
l'Aménagement et des
Réseaux (France)



Deutsches Zentrum für Luft-
und Raumfahrt (Germany)



University of Southampton
(United Kingdom)



University College London
(United Kingdom)



Imperial College London
(United Kingdom)



École Polytechnique Fédérale
de Lausanne (Switzerland)



Technical University of Crete
(Greece)



Europe Recherche Transport
(France)

Associated partners

Centre for Transport and Navigation (DVS), The Netherlands	KU Leuven University (CIB), Belgium	Technical University of Munich, Germany
CERTU, France	LCPC, France	Telenavis Hellas S.A., Greece
CETE Sud-Ouest, France	Link Technology S.A., Greece	TNO, The Netherlands
CITILOG, France	Motor Transport Institute-ITS, Poland	Traffic First, France
ECTRI, EU	Open University of Israel, Israel	Transport Research Laboratory, United Kingdom
Egis Mobilité, France	Pamukkale University, Turkey	Université Versailles St. Quentin-en-Yvelines (PRISM), France
ETRA, Spain	PATH, USA	University of Artois (LGI2A), France
Federal University of Santa Catarina, Brazil	Polis, EU	University of Auckland, New Zealand
Ford Otomotiv, Turkey	Polytechnic University of Hong Kong, China	University of Tokyo
Hellenic Institute of Transport, Greece	SODIT, France	Institute of Industrial Science, Japan
Ideal Technology, Turkey	Technical University Braunschweig, Germany	VicRoads, Australia
ISBAK A.S., Turkey	Technical University of Graz, Austria	
ITS Germany, Germany	Technical University of Istanbul, Turkey	
ITS-Edunet, EU		
ITS-Hellas, Greece		
KOTI, Korea		





Background

Why traffic management in a cooperative environment is still necessary

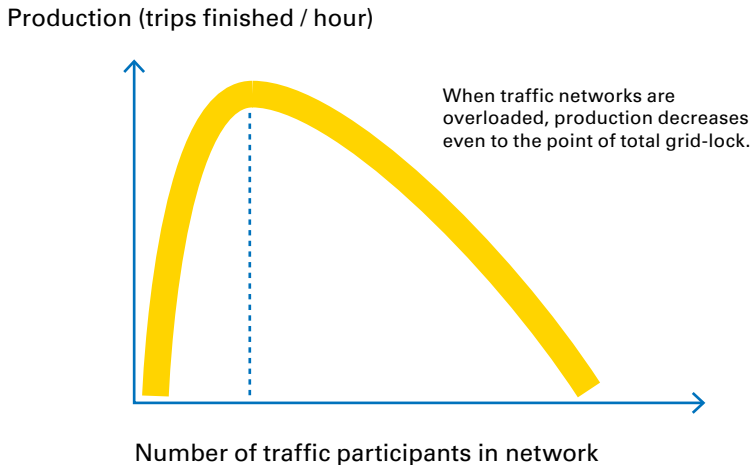
Vehicles developed in the near future will be technically advanced and intelligent. Cameras in these cars will scan the immediate environment, and wireless technologies will provide continuous contact with other vehicles and systems along the road. With such a cooperative system guiding intelligent vehicles, would an external form of guidance – traffic management – really be necessary? There can only be one answer to this question: yes, even in a cooperative environment, traffic management will be essential.

Consider the following analogy. What would happen in a highly sophisticated production facility with autonomous intelligent robots doing all of the processing and manufacturing if there would be a sudden power failure leading to the malfunction of one of the robots in the critical production chain? Under these circumstances, fast efficient central control and management facilities to monitor, reschedule and coordinate the robots would be pivotal in ensuring production. But this is only a case in point. From a wider perspective, advanced factory control and management facilities are required to identify all possible problems and redistribute tasks and capacities in either unforeseen circumstances (incidents, a sudden increase

in demand, etc.) or simply because of changed priorities or policies. No venture capitalist would invest in a factory without adequate control and management procedures in place.

Similarly, it would be inconceivable that societies would want to invest in cooperative vehicle technologies without investing in the supporting traffic control and management capacities. Intelligent vehicles require intelligent infrastructures managed and controlled by capable road authorities. Vehicle automation and a cooperative environment will greatly benefit traffic safety and convenience but they will not necessarily lead to efficient reliable transport systems unless a capable traffic control and

Network Fundamental Diagram



management is in place. In fact, such a situation could even produce adverse results.

Self-organisation versus self-deterioration

As long as traffic is flowing freely, intervention or coordination is unnecessary, other than for safety and efficiency purposes at intersections or other conflict points. The self-organising 'behaviour' of a traffic flow is similar to how birds and fish behave. This self-organising behaviour can be enhanced: a cooperative environment and vehicle intelligence based on real-time information provide advanced driver assistance with the potential for substantially increasing safety, convenience and efficiency. This has been

convincingly demonstrated in many research and development projects conducted in recent decades.

Self-organisation, however, no longer works once traffic networks become congested. Unlike water supply networks where higher pressure implies greater output, traffic networks self-deteriorate under pressure. If the number of vehicles in a network surpasses a critical point, production (the number of vehicles able to exit the network) plummets and can even result in a total gridlock.

Four reasons for a decrease in production

Research conducted throughout the world shows that there are four inter-

Background

related reasons for this decrease in production in congested traffic networks.

First, there is a significant drop in capacity¹ (up to 30%) once congestion sets in. This drop is probably caused by a combination of human driving behaviour, limitations in vehicle acceleration, and high levels of traffic heterogeneity.

Second, queue spillback causes blockages upstream of bottlenecks. This causes delays for travellers that did not have to pass the bottleneck in the first place and further accelerates the build-up of congestion and the decrease of performance.

Third, an unequal distribution of traffic over a network causes a further deterioration in performance. In a sense, congestion generates more congestion and simply exacerbates the situation.

Finally, individual route choice (which maximises individual objectives) in congested traffic – even when based on real-time information – is up to 30% less effective than system-optimal route choice. Simply put, what benefits an individual traveller may result in a worse situation for everyone in the congested situation.

Towards cooperative traffic control and management

Cooperative technologies that enable vehicles to communicate and share information with each other and the infrastructure offer tremendous opportunities for optimising traffic operations in modern traffic networks. Under freely flowing conditions, these technologies enable efficient self-organisation combined with high degrees of convenience and safety for individual travellers. Under congested conditions, these technologies enable advanced integrated and coordinated control methodologies that minimise delays and pollution and maximise the efficiency and reliability of urban mobility for everyone. How does this work?

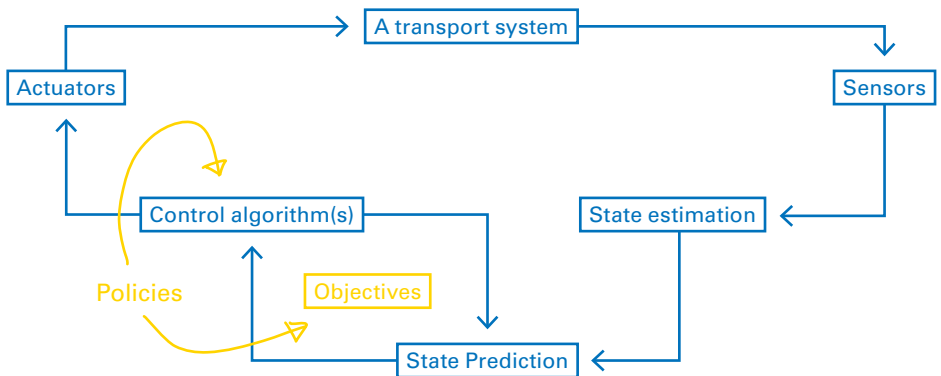
The figure on page 17 shows a classic traffic control cycle. In the first place, sensors and actuators provide the enabling technologies that make traffic control possible in transport systems ranging from intersections to entire multimodal transport networks. With in-vehicle technology, sensing may move partially – and even entirely, once every vehicle is connected – from the infrastructure to the vehicle. This transition could result in very substantial benefits because ‘floating sensors’ could offer additional (or richer) information such as destinations, routes, vehicle characteristics and driver preferences. This would enable more closely defined, accurate traffic prediction and thus better control. A similarly exciting prospect would be having actuation also shift

¹ The capacity is the ability of a road to accommodate traffic volume. The unit used is vehicle per hour (vph) or vehicle per hour per lane (vphpl).

Traffic Control Cycle

Transport systems

ICT, cars, infra



Traffic control and management

Managing/influencing transport system operations

partially or largely from infrastructure to vehicles. This would offer additional opportunities for making traffic control itself more effective (e.g. for automated driving and merging) and also make it more accepted by users.

These possibilities will not change societal objectives such as safety, efficiency and environmental impact or the relevance of traffic management (e.g. preventing capacity drop and spillback). Neither will they replace the underlying methodologies needed to understand traffic dynamics and the effects of traffic control and management. The main point is this: even sophisticated, fully automated traffic networks will come to a grinding halt due to gridlock effects without proper hierarchical control and management.

Over the last three decades, the traffic theory and control community has worked relentlessly, and with success, on developing the underlying theories and modelling approaches to describe and understand the complex traffic dynamics at different scales ranging from intersections to entire networks. Researchers have also made substantial progress in what is required in the way of control and management methodologies to combat congestion, improve safety and reduce environmental impact. Within the framework of NEARC-TIS, some of the EU's leading academic teams have collaborated to support the perpetuation of this knowledge and its use in the rapidly growing market for intelligent vehicles.





Results

What we already know and what we still have to discover about cooperative traffic management

As we indicated earlier, the objectives of the NEARCTIS project included drawing up a consistent research programme and disseminating knowledge. In other words: what do we already know about cooperative traffic management, what do we still have to discover about it, and how can we keep others informed? The NEARCTIS partners applied a structured approach to answering these questions in the form of certain work packages. What were the results?

Researchers have been acquiring knowledge about traffic control and management ever since the 1980s. During these past decades, countless traffic management measures and systems have been developed, tested and applied in actual situations throughout the world. The fact that traffic management has an advantageous effect on traffic flow, safety and liveability is thus beyond dispute. But with the emergence of intelligent cars and the promises offered by cooperative systems, it becomes important to take another look at what we already know about traffic management. After all, how can we ensure that traffic management will reinforce the possibilities offered by cooperative systems?

Identifying promising case studies

To answer this question, the NEARCTIS

partners reviewed the state of the art and identified case studies that provided the most potential for using cooperative technology to take traffic control and management to the next level.

Traffic control and management applications work at many scales ranging from single intersections to entire networks. Within the framework of NEARCTIS, we looked at existing applications used at all these scales. We reviewed global services (e.g. traffic information, road pricing) and applications for major highway corridors (e.g. coordinated ramp metering, dynamic speed limits), dense urban networks (coordinated intersection control), local main road networks (managed lanes), and shared multi-modal/multi-user networks (multi-modal information, surveillance and control systems).

In virtually all of these cases, many options were identified for applying cooperative technologies to enhance, improve and/or scale up existing ideas or to pave the way for entirely new ideas.

To illustrate, here are a few concrete examples that relate to highway corridor management. Stand-alone control measures such as ramp metering and route guidance offer considerable benefits by preventing capacity drop and distributing traffic more evenly over a network. Roughly speaking, every minute that congestion onset is postponed saves at least 2 to 3 minutes of delay. Multiply these delay savings with actual traffic demand in dense traffic networks, and the collective benefits of traffic control become apparent. This is particularly relevant since the cost for traffic control measures like ramp metering are at least two orders of magnitude less than the costs for infrastructure expansion.

The DACCORD and EUROCOR projects (mid-90s) had already convincingly demonstrated that coordinating ramp metering and information provision (routing) offers substantial additional benefits. Coordination effectively buys road authorities extra time to prevent and mitigate congestion. This was confirmed by a recent implementation of the HERO coordinated ramp metering algorithm on the Monash Freeway in Melbourne (2008). HERO reduced the space-time extent of congestion and provided significant improvements in throughput (5-8%) and travel speed (35-60%) during peak periods. The algorithm has been widely accepted by users and has also reliably improved

travel time on the corridor. To seal the case, the economic payback period for the pilot project was just eleven days (!). It would be expected that combining coordinated ramp metering with in-vehicle information and routing strategies, the effectiveness of both would be increased.

The same holds true for dynamic speed limits on longer road sections. This strategy is used to homogenise speeds (to improve traffic stability), reduce inflow into downstream bottlenecks, and/or as a solution for wide moving jams. When used for the latter purpose, the algorithm is called SPECIALIST. These approaches have been successfully tested under actual road conditions in the past few years. Using both in-vehicle sensing and actuation may dramatically increase effectiveness. An in-car version of SPECIALIST was developed in the lab and tested in controlled experiments, and a large-scale field trial is anticipated in the near future.

Cooperative systems thus offer potential for making advances in traffic management in all these areas and over all scales. This is particularly true of vehicle-to-infrastructure communications which could provide alternatives to sensors and actuators not only in terms of increasing performance, but also in terms of reducing costs.

What we still have to discover

The NEARCTIS partners have a vision of a future transport system in which widely shared information will be used to improve, manage and control transport – see some examples on page 23.

Results

Information will be communicated directly among vehicles and between vehicles and system infrastructure. This will support cooperation both among users and between road users and road managers. Value will be added to transport systems, and users will benefit from safer journeys, reduced travel times, less congestion and access to better information. All of this will improve the travel experience. Beyond this, improved cooperation will also benefit society as a whole by enhancing the operation of the transport system and reducing costs, fuel consumption and pollution.

This exciting vision is shared by many researchers and practitioners worldwide. Yet fundamental questions remain. How do we get there, and what research efforts will be required to support this transition? We are convinced that an interdisciplinary approach is key.

NEARCTIS identified seven research themes that could serve as building blocks to construct future interdisciplinary research efforts (see the figure on page 23, below). The first two – communication technology and access to ‘big data’ – would facilitate realising this vision. The next three research themes pertain to the mechanisms (the knowledge and methods) required to exploit these facilitators. These research themes include the estimating, predicting and modelling of traffic operations at all scales (from intersections to entire networks); the control

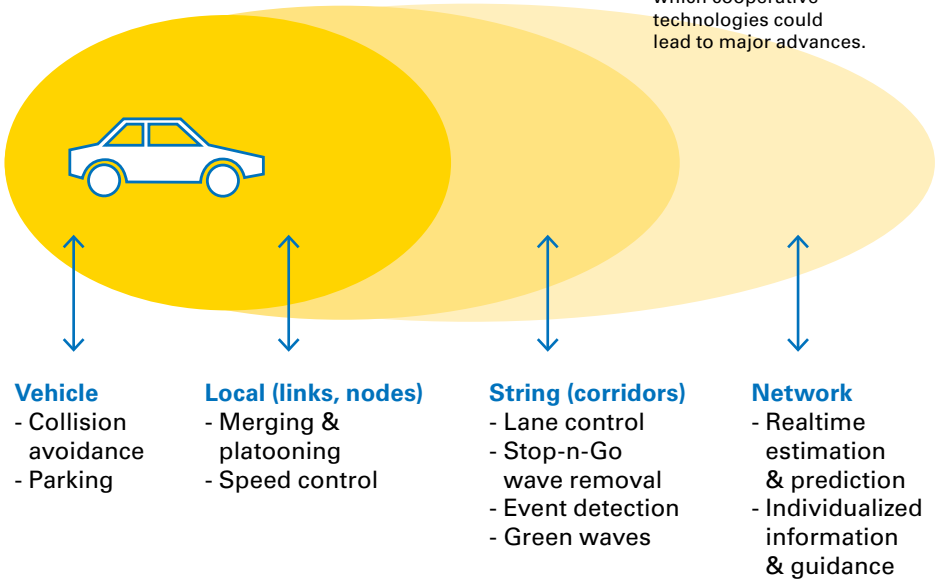
and communication logic needed at all scales (from vehicle-to-vehicle automation to area-wide routing and scheduling); and the interactions between the many objects and processes involved (e.g. coordination between users, between users and road managers and between automated and manual systems). The final two research themes relate to the ‘producers’: the application areas that include the actual transport systems, and the decision support tools for helping policymakers plan, manage and operate these systems.

The NEARCTIS research agenda identifies interdisciplinary research questions that address the facilitators, the mechanisms and the producers involved. Examples of these questions include: ‘How can we integrate traffic systems and the modelling of these systems using more up-to-date data?’, ‘How can we optimise and control traffic systems and operations during the transition from infrastructure-based sensing and actuation toward vehicle-based sensing and actuation?’, and questions related to impact assessment and evaluation.

Obviously, other facilitators, mechanisms and producers could yet be identified. The underlying point we are making is that cooperative transport systems in the high-tech cities of the 21st century will require collaborative and interdisciplinary research efforts that combine expertise from the ICT sciences, the traffic and transport sciences, the automobile industries,

Cooperative applications

Examples of control and management applications at different scales in which cooperative technologies could lead to major advances.



Identified research themes

Facilitators

(1) Communication technology

(2) 'Big data' availability

Mechanisms

(3) Improved transport modeling on all scales

(4) Control, communication & automation on all scales

(5) Managing & coordinating interactions on all scales

Producers

(6) Effective large-scale transport systems

(7) Decision support tools for policy makers

Results

the EU road authorities and many other stakeholders. The Google car has demonstrated that autonomous driving is not a sci-fi fantasy. However, there is much more to having transport systems that are accessible, ubiquitous, efficient, safe and clean than vehicle automation alone. We need a fundamentally new understanding of how such cooperative transport systems operate at all scales and how traffic management and control can help address the societal challenges outlined in the Horizon 2020 programme for developing sustainable transport and mobility.

Shareable resources

As part of the EU research community, we also looked into which research facilities such as data, software, teaching material, etc. we could share for the purpose of simplifying the research conducted to answer these research questions. With the need to share facilities proving to be essential, we drew up a large database containing shareable resources that the entire NEARCTIS network could utilise.

How to keep others informed

A new interdisciplinary paradigm for most of the parties involved in road and traffic management (road managers, researchers, policymakers) necessitates new skills in traffic management and all its interconnected disciplines. Working within NEARCTIS, we reviewed the many available courses and training activities in traffic management across the EU. The review identified the variations in the quality

and quantity of this training across the European member states and supplied recommendations concerning syllabus requirements and raising the level of education and training to a more uniform standard across Europe.

By contrasting this review of existing courses with the identification of new needs, we could identify gaps and design new professional courses to fill the gaps. NEARCTIS proposed a structure consisting of five new professional courses for cooperative traffic management that would be provided at a standard level throughout European. These courses are:

- Driver information systems
- Traffic signal and public transport priority
- Motorway traffic control methods and tools
- Microscopic modelling and simulation
- Traffic state estimation and data fusion methods

These courses would cover methodological areas as well as traffic management application areas.

NEARCTIS also initiated its own new training programme that consolidated multidisciplinary competences and offered advanced courses in the most relevant disciplines. These NEARCTIS Summer Courses are considered key successes in the NEARCTIS project. Over 100 students from both our core members and associated partners par-

ticipated in three intensive 3-day summer school sessions aimed at learning and working together with experts from the NEARCTIS institutions and the partners of NEARCTIS. The positive effects of these short courses have motivated most of the instructors to perpetuate this type of training activity in the future. Teaching cooperative traffic management needed to be supported by ICT facilities to enhance its effectiveness. ICT could be used to distribute teaching content tailored to specific trainees according to their knowledge and needs. It allowed for interactive tutorials, subjects to be explained at different levels, and problem-based

learning. To support this, the database of shareable resources we developed (case studies as well as data sets, open source software and teaching materials) was readily accessible during the summer school sessions.

Perhaps the most important resource-sharing activity within NEARCTIS was the NEARCTIS Mobility Programme that facilitated eleven short-term visits made by young researchers to other NEARCTIS institutes. These exchanges and the collaborative research efforts they prompted have been a strong motivating force for continuing the NEARCTIS efforts.

Achievements

- Developing a common EU research agenda in cooperative traffic control and management that can be used to inspire and feed into Horizon 2020.
- Compiling a set of leading case studies in Europe that can be used to test new cooperative traffic management strategies.
- Drawing up the education and training options and requirements in cooperative traffic management.
- Delivering effective training and research exchanges including (i) three intensive 3-day summer school sessions that attracted over 100 PhD students and (ii) exchanges between NEARCTIS partners for eleven young researchers.
- Generating a common database of shareable resources (software, data, case studies, etc.) for NEARCTIS researchers.
- Building towards a virtual European centre of excellence in cooperative traffic control and management that will act as an independent knowledge institute and liaison in Europe.



Future



Future

Toward a centre of excellence in cooperative traffic management

The final conference in Dublin in June 2013 will mark the official conclusion of the NEARCTIS project. Yet both the core members and the associated partners of NEARCTIS realise that the only way to take on future research challenges effectively and efficiently is for us to *continue* our collaboration. This could be accomplished informally, but might it also be possible to carry on the NEARCTIS alliance within an official centre of excellence?

After five years of sharing work and engaging in intensive academic exchanges, the NEARCTIS partners (both the core team and the associates) have expressed a strong desire to continue their productive teamwork.

New training programmes

One area in which the partners want to continue their communal efforts is the training of young researchers. The summer school sessions and exchange programmes were a tremendous success. Substantial organisational experience was also acquired over the last few years. All reasons, therefore, to continue the path already taken. The focus of the new training programmes could be applying theoretical scientific research to practical situations. This might be done by expanding the current training programme into an Initial

Training Network (ITN) in the Marie Curie programme, and this is exactly what the NEARCTIS partners are now working on.

Virtual centre of excellence

Even more fundamental is the desire to perpetuate the teamwork involved in such activities as promoting and jointly implementing the research agenda, sharing resources and publications, and responding to certain calls from the EU and national funding bodies.

To achieve this broader objective, we plan to work progressively on building a virtual centre of excellence (VCE). At first, this association will take on the character of an informal circle consisting of former members of NEARCTIS. During this initial period, these partners will be committed to examining

the possibility of creating a more substantial association, probably under French law. Actually doing things together has been and will continue to be the key to the success of NEARCTIS. A more formal association does not necessarily imply a large or expensive organisational structure, but it does require an audience. We hope the NEARCTIS efforts and a possible follow-up in the form of a VCE will put traffic control and management more firmly on the EU Horizon 2020 agenda.

In conclusion

As a project, NEARCTIS has achieved all of its proposed objectives. Its research deliverables are useful and beneficial and will remain so in the years to come. If we really want to make the tempting promises of cooperative systems come true, however, follow-up

steps will be needed, especially in 'our' field of traffic control and management. If we seriously devote ourselves now to continuing and expanding our cooperation at the European level, it will be just a matter of a few years before we will be harvesting the sweet fruits of success: a modern, co-operative traffic system that uses intelligent traffic management to remain stable and efficient, even during peak traffic periods. Perhaps by that time, we can agree that the foundation for that success was established during the NEARCTIS project.





Colophon

For more information

All the reports and research deliverables resulting from the NEARCTIS project are available at www.nearctis.org.

For more information, please send an e-mail to info@nearctis.org or contact Nour-Eddin El Faouzi, IFSTTAR, tel. +33 4 72 14 25 43.

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