ERA-NET Road – Mobility

Getting the most out of Intelligent Infrastructure

Final Report

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Executive summary

The overall aim of the trans-national joint research programme **ENR 2011 "Mobility – Getting the most out of Intelligent Infrastructure**" was to improve the management of the European road network. The research focused on identifying the challenges faced by National Road Administrations (NRAs) in embracing new techniques to get the most out of the existing network and assist road authorities in identifying feasible, valid and cost-effective solutions for key European roads.
The programme was based on four objectives, with the concepts of:

A) Impact Assessment of Intelligent Transport Systems (ITS)

B) Effective Distribution of Road Authority Data

C) High Quality Traffic Management/Information Data and Incident Detection

D) Implementation of Short Term Prediction

The research programme sought to understand how to get the most out of Intelligent Infrastructure from a road operator point of view. These objectives have been developed following a series of workshops involving specialists from each of the Road Administrations partners. In these workshops, it was recognised that benefits of intelligent infrastructure systems need to be included in business cases. In addition to all of the above, objectives needed to consider value for money, whole life costing, sustainability and the environment for the road operator.

Five projects were funded in the research programme and were carried out during 2011-2013. The tools, models and methodologies developed in the five projects provide road administrations with the necessary knowledge on:

- Which cooperative services deliver maximum benefit and enable road operators to manage road networks more cost-effectively;
- What are the prerequisites for seamless use and distribution of traffic data to third parties, such as service providers and in-vehicle devices;
- How to evaluate the quality of traffic data and mitigate the associated risks of erroneous data on motorways and urban road environments;
- What are the requirements to improve traffic incident management, as well as the novel technologies that could help decrease the overall costs of detection;
- What are the requirements needed for the implementation of a real-time modelling tool in a traffic control centre, from the technical aspects to the user interface and user acceptance.

COBRA (Cooperative Benefits for Road Authorities) aimed to aid road authorities in optimally benefiting from changes in the field of cooperative systems (CS). This was done by providing an insight on the costs and benefits of possible investments, both from a societal and business case perspective.

The main outcome was a decision support tool, which enables the costs and benefits of the three bundles of cooperative services to be compared in various contexts, to support road administrations on investment decisions under different deployment scenarios.

SEAMLESS (Seamless Traffic Data Dissemination across urban and inter-urban Networks) aimed to achieve seamless dissemination of data in urban and inter-urban networks through harmonized data protocols.

The main outcomes of the project were a generic architecture applicable to multiple use cases, which can be used by NRAs, as well as a set of DATEX II profiles, modified for two specific use cases (Traffic Light Phase Assistant and Seamless urban and inter-urban roads information for in-vehicle devices).

RAIDER (Realizing Advanced Incident Detection on European Roads) focused on improving incident detection on motorways and secondary roads by incorporating novel technologies such as roadside systems, in-vehicle systems and nomadic devices.

The main outcome was a set of generic specifications on the performance and costs of novel technologies, as well as the implications of different configurations according to the specific needs of NRAs.

QUATRA (Software and Services for the Quality Management of Traffic Data) aimed to develop procedures and software tools for the evaluation of traffic data quality on freeways and urban road environments.

The outcome was the development of two tools: one that focuses on the quality evaluation of incoming freeway traffic data online for quick response in case of abnormal traffic conditions, and one based on a similar process for cities, working offline for efficient scheduling of repairs of faulty traffic detectors.

STEP (Short Term Prediction) had the objective of implementing and testing representative solutions for real-time traffic modelling in an operational environment, for providing generic recommendations to European Traffic Control Centres (TCCs).

A short-term traffic prediction tool was evaluated in a real-life situation, in order to gain a better understanding of the potential obstacles that may arise in terms of prediction quality, data availability, technical deployment and user acceptance and provide solutions for improvement.

The **ERA-NET ROAD** concept encourages the exchange of knowledge between National Road Administrations in Europe and gives them the opportunity to improve the quality of European roads, while reducing costs.

As the joint programme comes to an end, some overall recommendations for future programmes can be given:

- More emphasis needs to be put on the implementation aspect of the results;
- The results (tools, models, specifications) should be disseminated across CEDR member countries;
- Active involvement of NRA stakeholders is crucial to any research project, as they are the main users of the results;
- More interaction between the projects would be valuable and help enhance the results;
- The outcomes of the joint programme should be used as a basis for further research work.

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Introduction

"ERA-NET ROAD – Coordination and Implementation of Road Research in Europe" was a Coordination Action funded by the 6th Framework Programme of the European Commission. The partners in ERA-NET ROAD (ENR) were United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark. Within the framework of ENR, the trans-national joint research programme ENR 2011 "Mobility – Getting the most out of Intelligent Infrastructure" was initiated. The funding partners of this cross-border funded Joint Research Programme are the National Road Administrations (NRAs) of Belgium, Switzerland, Germany, Netherlands, Norway and United Kingdom. The research budget was EUR 1.7 million and 22 proposals with 73 partners from 11 different countries were submitted.

The overall aim of the programme was to improve the management of the European road network. The research focused on identifying the challenges faced by NRAs in embracing new techniques to get the most out of the existing network and assist road authorities in identifying feasible, valid and cost-effective solutions for key European roads.
The programme was based on four objectives, with the concepts of:

A) Impact Assessment of Intelligent Transport Systems (ITS)

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D) Implementation of Short Term Prediction

The research programme sought to understand how to get the most out of Intelligent Infrastructure from a road operator point of view. These objectives have been developed following a series of workshops involving specialists from each of the Road Administrations partners. In these workshops, it was recognised that benefits of intelligent infrastructure systems need to be included in business cases. In addition to all of the above, objectives needed to consider value for money, whole life costing, sustainability and the environment for the road operator.

Five projects were funded in the research programme and started in 2011:

- **COBRA** – Cooperative Benefits for Road Authorities
- **SEAMLESS** – Seamless Traffic Data Dissemination across urban and inter-urban Networks
- **RAIDER** – Realising Advanced Incident Detection on European Roads
- **QUATRA** – Software and Services for the Quality Management of Traffic Data
- **STEP** – Short Term Prediction

All project reports and deliverables can be downloaded from the ERA-NET website: **http://www.eranetroad.org.**

At the conclusion of the programme, a one day conference was organised to present the results and overall conclusions of the five projects. The conference was held on September 27th, 2013 in Vienna, Austria and was hosted by the AIT Austrian Institute of Technology. Two parallel group discussions were carried out, with focus on the implementation of the project results, as well as remaining open questions.

The aim of this report is to summarise the findings and recommendations from the five projects and emphasise how road authorities can implement the results of all projects in a proficient manner.

1 Project descriptions

This chapter presents the five projects selected in the joint research programme. A brief introduction of the project, along with a set of objectives and outcomes and further explanations of the results can be found for each project.

1.1 COBRA – Cooperative Benefits for Road Authorities

Duration: 01.09.2011 – 01.02.2013

Budget: EUR 415.000

Coordinator: Kerry Malone, The Netherlands Organization for Applied Scientific Research (TNO), The Netherlands

Partners: Transport Research Laboratory (TRL), United Kingdom

Austrian Institute of Technology (AIT), Austria

University of Amsterdam, The Netherlands

The COBRA project aimed to aid road authorities in optimally benefiting from changes in the field of cooperative systems (CS). This was done by providing an insight on the costs and benefits of possible investments, both from a societal and business case perspective. The main outcome was a decision support tool, which enables the costs and benefits of the three bundles of cooperative services to be compared in various contexts, to inform investment decisions under different deployment scenarios.

To meet its objectives, COBRA evaluated the state of the art of cooperative systems and chose 10 functions (see Table 1), which were considered the most likely to be deployed in the near future. The functions were grouped in three bundles. The selection of bundles was based on the assumption that due to technical requirements (wireless vs. cellular communication) as well as implementation costs and legal issues, cooperative systems will likely be deployed in a bundle, rather than as individual systems.

Table 1 Bundles of cooperative services

Bundle	Function
Bundle 1 Local dynamic events	Hazardous location notification Road works warning Traffic jam ahead warning eCall
Bundle 2 In-vehicle speed and signage	In-vehicle signage Intelligent speed adaptation Dynamic speed limits
Bundle 3 Information services	Traffic info and recommended itinerary Multimodal traffic information Parking information and guidance

A literature based impact assessment was performed in terms of safety, traffic efficiency and environment, to determine positive or negative impacts that can be expected with CS implementation. A cost benefit analysis (CBA) was then conducted to translate the impacts to costs and monetised benefits. These two steps provided the necessary input data for the decision support tool developed in this project.

Objective	Outcome
An overview of the "state of the art" regarding the deployment of CS and the roles of various actors	An in-depth review of existing CS was performed, by studying European and international developments. An analysis was done to find out what CS technologies are likely to become feasible in the medium to long term. An inventory of existing legal frameworks was collected. (see Deliverable 1, [1])
An overview of requirements for decision making on the deployment of CS	After an initial stakeholder workshop with road administrations, a list of needs and requirements for road authorities was created. (see Deliverable 2, [2])
An analysis of the expected impacts of CS in terms of safety, traffic efficiency and environment	An extensive literature review was performed and the results from more than 20 studies were used to produce an impact assessment matrix. No additional field operational trials or simulations were performed in COBRA. (see Deliverable 3, [3])
A cost benefit analysis, based on the impact assessment and given investments and maintenance costs	The CBA was based on the concept of welfare economics and the techniques employed were based on various European projects. The principle of making conservative estimates was adopted, to reduce the likelihood of over-optimistic assessments. (see Deliverable 4.1, [4])
Development of a support tool for providing support to road authorities	An Excel-based tool was developed, that enables cost and benefits of the three bundles of services to be compared in various contexts, to support road authorities on investment decisions under different deployment scenarios. (see Deliverable 4.2, [5])
An analysis of the legal issues that play a role CS deployment	Analysis of existing framework, liability, data protection and privacy issues. (see Deliverable 5, [6])
A clear set of recommendations for road authorities on the actions to be taken for the enabling of cooperative systems, including a roadmap to meet the challenges for implementation	Based on a set of criteria established at an internal consortium workshop, migration paths were developed that show what road administrations need to do to deploy the CS investigated in COBRA. (see Deliverable 5)

The decision support tool is an Excel spreadsheet, which enables to compare the costs and benefits of the three bundles of services in various contexts, to inform investment decisions under different deployment scenarios. The deployment scenarios describe the implementation of cooperative systems, in addition to any existing road-side services.

The tool also allows the business case to be investigated for delivering services under different business models. These models have been created according to the degree of responsibility of the road authority for setting up and operating the services. Therefore, the deployment contexts can be public, private or mixed. Options within the tool also enable users to choose between the two communication platforms, cellular network or wireless beacons. The tool is usable at the moment only for United Kingdom (UK) and the Netherlands, but can be adapted by road administrations by providing additional country-specific data.

Figure 1 shows the input scenarios and the options available, while Figure 2 represents an output page, where the user can see an overview of the two scenarios selected, from a societal and business case perspective.

Furthermore, the project performed an analysis of the legal issues that involve cooperative systems and provided recommendations, in the form of migration paths, for road authorities.

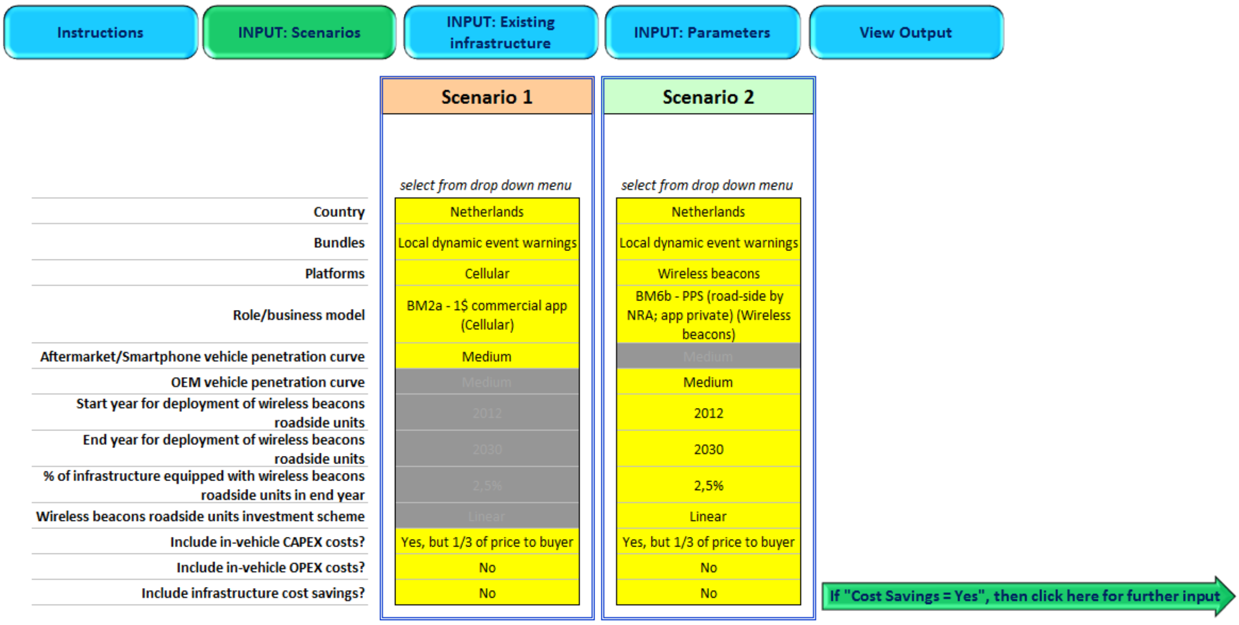

Figure 1 COBRA tool - input scenarios

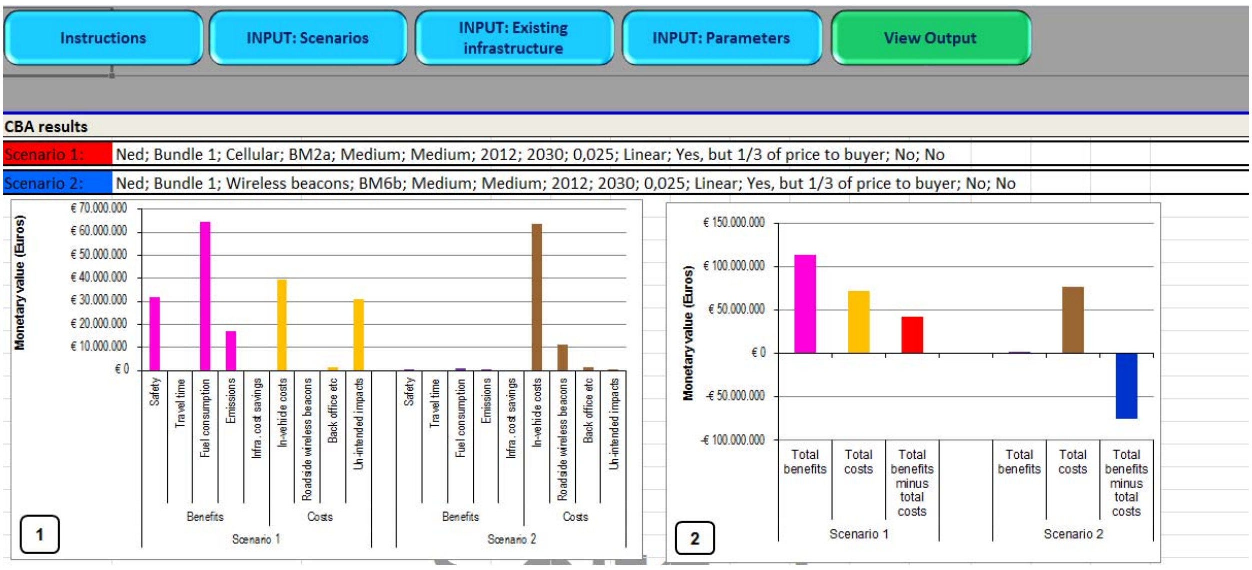

Figure 2 COBRA tool - Output

1.2 SEAMLESS – Seamless Traffic Data Dissemination across urban and inter-urban Networks

Duration: 01.10.2011 – 31.10.2012

Budget: EUR 260.000

Coordinator: Dr. Josef Kaltwasser, AlbrechtConsult GmbH, Germany

Partners: Mott MacDonald Limited, United Kingdom

Trafficmaster Ltd., United Kingdom

PTV Planung Transport Verkehr AG, Germany

The aim of the project was to achieve seamless dissemination of data in urban and inter-urban networks through harmonized data protocols. The development and implementation of new technologies (e.g. cooperative systems) will bring new sources of data, new end users and new communication channels. The provision of ITS services across geographical, technical and jurisdictional boundaries should be achieved without the user recognising a transition. Therefore there is a need for cooperation and harmonisation of data protocols. The main outcomes of the project were a generic architecture applicable to multiple use cases, which can be used by various NRAs, as well as a set of DATEX II profiles, modified for two specific use cases (Traffic Light Phase Assistant and Seamless urban and inter-urban roads information for in-vehicle devices).

Objective	Outcome
In-depth research on road data dissemination to in-vehicle devices	A literature review was performed to assess the research done in the area of cooperative systems, with focus on two use cases. (see Deliverable 1, [7])
Description of stakeholder needs, roles of various actors	An analysis of the roles, needs and objectives of both public and private stakeholders was performed. (see Deliverable 1)
Description of existing data standards	National, European and international data standards were described and analysed. For infrastructure: UTMC (UK), OTS (Germany), DATEX II (EU). For services and vehicles: TMC, TPEG, ETSI, ISO/CEN. (see Deliverable 1)
Analysis of business case	To better understand what stakeholder cooperation would entail, in terms of the data exchange along the value chain, a technical analysis was performed on: detection and provision of content, exchange of data and dissemination to end user. (see Deliverable 2, [8])
Development of a generic architecture	The architecture shows how central, roadside and mobile stations are linked and communicate with each other. Additionally, the architecture was applied to the two specific use cases in the project. (see Deliverable 3, [9])
Mapping SEAMLESS model to existing data standards	The SEAMLESS reference model was mapped to reference architectures for existing standards, such as UTMC and OTS. (see Deliverable 3)
Harmonisation of protocols and data profiles	DATEX II profiles were modified for the two specific use cases and are ready for use. (see Deliverable 4, [10])

A review of relevant projects that investigated cooperative systems was performed. The research was afterwards narrowed on two specific use cases, which were the focus of the project:

- Traffic Light Phase Assistant – traffic light broadcasting timing data associated with its current state. When the information is received (e.g. time interval before turning red), a speed advice can be given to the driver according to its relative distance to the traffic light and its current speed.
- Seamless urban and inter-urban roads information, for in-vehicle devices, with journey times as a particular focus – relevant, accurate information supporting an informed route choice. Data on delay, weather, speed etc. can be obtained through a smartphone application or a dedicated in-vehicle device.

As the organisational framework of the two use cases involve both public (e.g. road operators) and private (e.g. automotive industry, service providers) stakeholders, an analysis of the objective, roles and goals of the involved parties was performed, in order to evaluate how the stakeholders work together along the value chain. In addition, to better understand how seamlessness can be achieved, a review of existing communication standards was performed: UTMC (Urban Traffic Management and Control, UK), OTS (Open Traffic Systems, Germany), DATEX II (EU), TPEG (Transport Protocol Experts Group), etc.

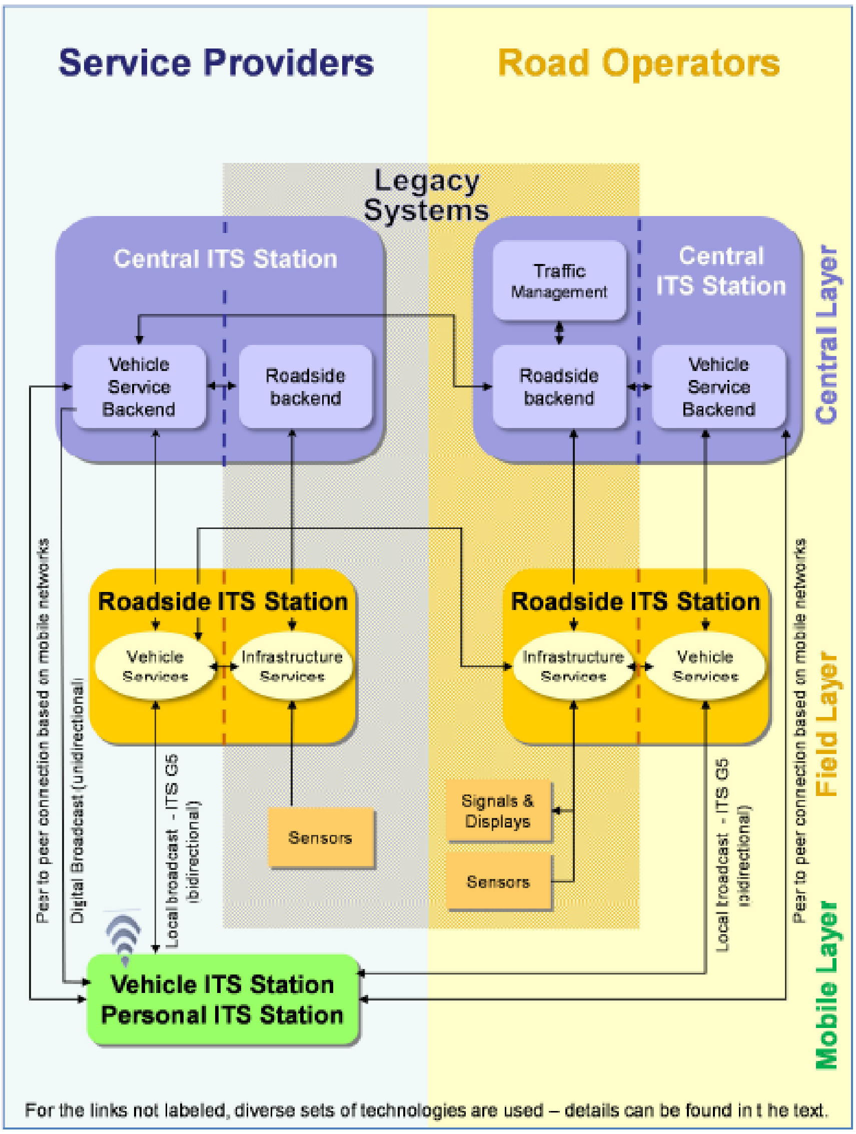

Figure 3 SEAMLESS – Generic architecture

An in-depth analysis of the exchange and flow of data along the value chain was done, to better understand the technical requirements for stakeholder cooperation. The process was divided in three cases: detection and provision of content, exchange of processed data and presentation of information to the end user. Based on this analysis, the business case for the seamless character of urban services especially in relation to legacy systems was developed.

To optimally show how to support seamless urban and inter-urban services, the project developed a generic architecture that links the various parties involved. The model covers all relevant cooperative ITS components and communication channels. Figure 3 shows in detail the different layers of the architecture: Central (Central ITS Station), Field (Roadside ITS Station) and Mobile (Vehicle/Personal ITS Station). The aim was to be able to use this architecture by applying it to specific situations and systems, according to the services and functionalities of a specific scenario.

For this purpose, the architecture was applied to the use cases analysed in the project. Based on the generic structure, derived architectures were described, depending on the communication chains and the roles of the involved parties.

Figure 4 shows the scenario for Traffic Light Phase Assistant via a Service Provider. The traffic light information is gathered from the central component of a road operator or from the central system. The customer for this information is a service provider, which receives the data and broadcasts it to the vehicles. The link between the two central ITS stations might be built on a DATEX II connection. DATEX II is a standard developed for exchange of information between traffic management centres and service providers.

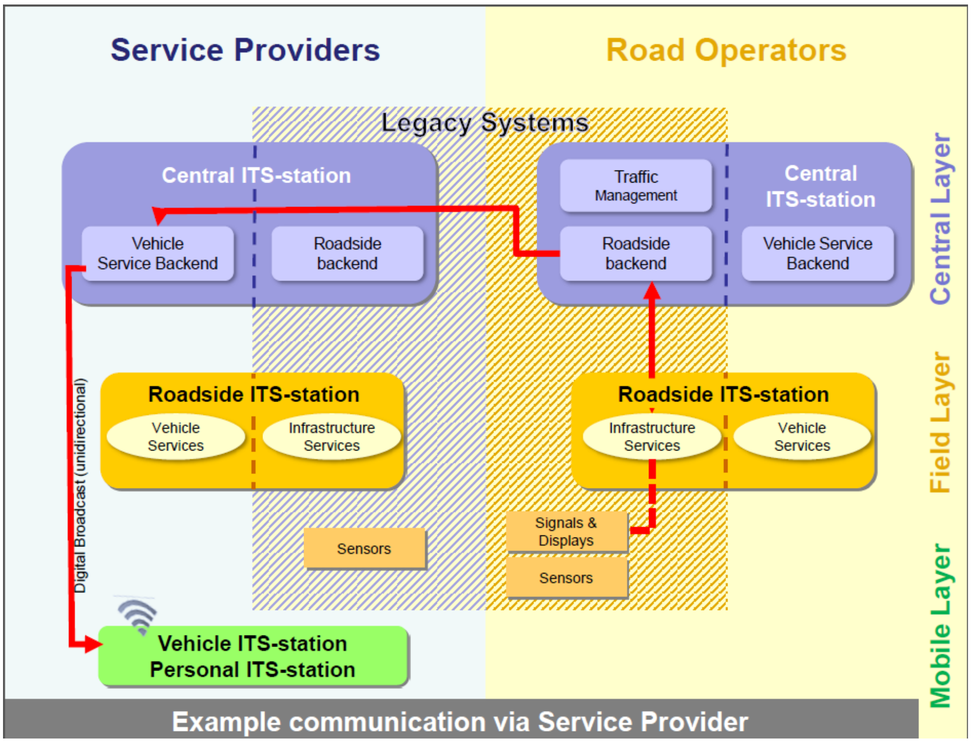

Figure 4 SEAMLESS Use case – Traffic Light Phase Assistant via Service Provider

The project showed how to harmonise protocols for the two use cases considered. As different data is specified in different protocols, there is the need for adaptation and harmonisation. DATEX II models and profiles were presented and explained for Traffic light information and Travel times and traffic condition. These profiles are ready for use.

1.3 RAIDER – Realising Advanced Incident Detection on European Roads

Duration: 01.11.2011 – 28.02.2013

Budget: EUR 320.000

Coordinator: Toon Beeks, The Netherlands Organization for Applied Scientific Research (TNO), The Netherlands

Partners: Transport Research Laboratory (TRL), United Kingdom

Austrian Institute of Technology (AIT), Austria

Forum of European National Highway Research Laboratories (FEHRL), Belgium

The focus of the project RAIDER was to improve incident detection on motorways and secondary roads by incorporating novel technologies such as roadside systems, in-vehicle systems and nomadic devices. These new technologies can improve the quality of detection, reduce the estimated costs of incident detection systems and improve incident management overall. The outcome was a set of generic specifications on the performance and costs of novel technologies.

Objective	Outcome
Identification of most relevant incidents and selection of top priority types of incidents	Stakeholder consultations were performed by means of questionnaires and interviews and three types of incidents were chosen for research: accident, extraordinary congestion and vehicle breakdown. (see Deliverable 2.1, [11])
Defining user needs and requirements for incident detection	Through the stakeholder consultations, the user needs and requirements for the selected incidents were defined. (see Deliverable 2.1)
Evaluation of state of the art in incident detection technology and products	A literature review was performed on current and new detection technologies such as inductive loops, radar, eCall, nomadic devices and in-vehicle systems. (see Deliverable 2.1)
Defining a set of performance indicators for the evaluation of detection systems	Four performance indicators were identified: Detection Rate, Detection Accuracy, Detection Time and False Alarm Rate. (see Deliverable 2.1)
Performance assessment of proposed technologies	A feasibility study was performed on innovative technologies such as eCall, cooperative systems (CS), nomadic devices and new roadside technologies. (see Deliverable 4.1, [12])
Defining generic specifications for improving existing incident detection systems	A set of generic specifications on the performance and costs of novel technologies, as well as the implications of different configurations according to the specific needs of NRAs. (see Deliverable 4.1)
Development of use cases	Several use cases were defined, as examples for the decision process of NRAs. (see Deliverable 4.1)
Recommendations on innovative technologies	A set of recommendations on innovative technologies are given in the context of technical requirements for incident detection. (see Deliverable 5.1, [13])

Stakeholder consultations were organized by means of questionnaires and interviews to identify the most relevant incidents. Three top priority incidents (see Table 2) were chosen based on their impact on traffic safety and efficiency in critical situations: accidents, extraordinary congestion and vehicle breakdown. For these three incident classes, the consultations also provided an insight in the user needs and requirements. A literature review was also performed to analyse and evaluate the existing technologies currently used for incident detection, as well as identify the novel technologies that could improve incident detection.

Table 2 Types of incidents

Accident	The collision of one motor vehicle with another road user, a stationary object, or person
Vehicle breakdown	The operational failure of a motor vehicle such that the vehicle is slowed down considerably or becomes stationary
Extraordinary congestion	Unpredictable congestion caused by extraordinary events like abnormal traffic flows, traffic accidents, broken down vehicles, vehicle fires, wrong-way driving, road works or weather events

Cooperative systems, eCall, nomadic devices, as well as new roadside detection technologies (e.g. video tracking) were taken into consideration as novel technologies that can provide optimum incident detection. A performance model was built for each new technology, based on detection performance and their availability and penetration rate by the year 2020. Detection performance was characterized in terms of Detection Rate (DR), Detection Accuracy (DA), Detection Time (DT) and False Alarm Rate (FAR). A performance assessment was then performed, by evaluating the suitability of these technologies for the three types of incidents selected for research. This assessment led to a set of generic specifications applicable by any NRA, depending on its own needs and requirements.

Accident Detection (by 2020)

Technology	*DR*	*DT*	*FAR*	*LA*	*Vehicle Class & Dangerous Goods*	*Suitability*
eCall	Low	Medium	Low	High	Both	Low
Cooperative Systems configuration 1 (ITS G5 + RIS)	Low	Low	Low	Very High	Both	Low
Cooperative Systems configuration 2 (3G)	Low	Medium	Low	Very High	Both	Low
Nomadic Devices	Medium	High	High	High	No	Medium
Scanning Radar	High	Low	High	Very High	No	High
Video Tracking	High	Low	Medium	Very High	Both*	High

(by 2030)

Technology	*DR*	*DT*	*FAR*	*LA*	*Vehicle Class & Dangerous Goods*	*Suitability*
eCall	Medium	Medium	Low	High	Both	Medium
Cooperative Systems configuration 1 (ITS G5 + RIS)	High	Low	Low	Very High	Both	Very High

Figure 5 RAIDER – Performance assessment for Accident detection by 2020

Figure 5 shows the performance assessment of various technologies for accident detection by 2020. For example, as the penetration rate of cooperative systems will likely be low in

2020, they are recommended as replacement and deployment strategy for incident detection after 2030.

To demonstrate how to use the generic specifications for assessing innovative technologies, multiple use cases were analysed. The project developed five use cases, from the possible 36, by combining three road network types, two traffic flow situations and six existing sensor systems. These were chosen for their relevance to European NRAs. Each use case defines the current situation of a road authority, in terms of road network, traffic volume and existing detection systems. The performance requirements for each type of incident were then evaluated and technology options were presented, along with cost estimations. The costs were evaluated as overall setup, maintenance and operation costs of the respective technology.

Option	Technology	Suitability				Costs		
		Accidents	Break downs	AID	Conges-tion	Setup	Maint.	Oper.
1	Inductive Loop Detectors							
	Upgrade for tracking	Low	Low	Low	High	€	No extra costs	
	Fusion of ILD and RS tracking			High				
2	eCall					€	€	€
	2020 (PEV = 10%)	Low*)						
	2030	Medium*)						
3	Nomadic Devices					€	€	€€€/€
	events	Medium	Medium					
	RS vehicle tracking of nomadic devices			*Medium*				
	Traffic Data, FCD, Travel time data				Medium			
4	Cooperative systems							
	Configuration 1 (ITS G5)					€€	€€	0
	2020 (PEV = 5%)	Low	Low	Medium	Medium			
	2030	Very High	Very High	Very High	Very High			
	Configuration 2 (3G)	Low	Low	Medium	Medium	€	€	0
5	Video Tracking (upgrading CCTV system)	High	High	Very High	Very High	€€	No extra costs	
6	Scanning Radar	High	High	Very High	Very High	€€€	€	€€€/€

*) provides only events for major accidents

Figure 6 RAIDER Use Case – Options for incident detection systems

Figure 6 shows one example of a use case: motorway without hard shoulder, high traffic volume, and standard roadside equipment (inductive loop detectors installed each 500 meters). Six technologies are presented as the most relevant candidates in terms of performance and costs. This analysis would give NRAs the possibility to choose the option that best suits their needs and requirements.

1.4 QUATRA – Software and Services for the Quality Management of Traffic Data

Duration: 01.10.2011 – 30.09.2013

Budget: EUR 290.000

Coordinator: Friedrich Nadler, nast consulting ZT GmbH, Austria

Partners: Transver GmbH, Germany

The main objective of the QUATRA project was to develop procedures and software tools for the evaluation of traffic data quality on freeways and urban road environments. Data quality and recognition of erroneous data are an essential part in the decision making process for traffic authorities. The output was the development of two tools: one that focuses on the quality evaluation of incoming freeway traffic data online for quick response in case of abnormal traffic conditions, and one based on a similar process for cities, working offline for efficient scheduling of repairs of faulty traffic detectors.

Objective	Outcome
In-depth literature review of existing evaluation systems	The current state of the art was evaluated for gathering knowledge on existing methods, in terms of technical and traffic engineering approaches. (see Deliverable 2.1, [14])
Collection of research concepts that could be integrated in the software proposal of the project	The software LOTRAN-DQ developed by Transver, was taken as the basis for the development of the software tools. (see Deliverable 2.1)
Definition of user requirements	Workshops with Austrian and German road authorities led to the development of three use cases: labelling of erroneous data for traffic statistics, monitoring of operations and sensor availability and reconstruction of the traffic situation for traffic control purposes. (see Deliverable 4.1, [15])
Development of a strategy for traffic data assessment	A combination of a statistical model with a variety of local/global/plausibility indicators was used for traffic data evaluation. (see Deliverable 4.1)
Development of procedures and software tools to measure and estimate the quality of incoming online traffic data in a freeway control centre	An online tool was developed, capable of processing and evaluating the quality of incoming freeway traffic data. (see Deliverables 5.1 and 6.1, [16])
Development of a comparable service for the evaluation of urban traffic data for cities and their transport authorities	The offline tool has the ability of evaluating the quality of urban traffic data. (see Deliverables 5.1 and 6.1)
Evaluation of developed tools through field trials	Tests were performed on Austrian and German road sections, for both tools, with promising results. The tools are able to reliably detect abnormal traffic conditions. (see Deliverables 5.1 and 6.1)
Development of a business concept	Both tools will be provided free of charge. Revenue will come from installation and maintenance fees. (see

	Deliverables 5.1 and 6.1)

An in-depth review of the current state of the art was conducted, in order to gather knowledge on existing traffic data evaluation methods, in terms of technical and traffic engineering approaches. Guidelines and standardised procedures were also reviewed. In addition, various research concepts were collected, by studying what are the current systems in use and what could be integrated in the software approach of the project. Therefore, the software LOTRAN-DQ, developed by Transver – one of the consortium partners – was taken into account during the software development.

Workshops with road authorities in Austria and Germany helped to define the user requirements that could be met with the outputs of this project. Three use cases were defined as a result of the discussions: labeling of erroneous data for traffic statistics, monitoring of operations and sensor availability, reconstruction of the traffic situation for traffic control purposes.

Based on the literature review, a traffic data assessment strategy was developed. The evaluation of urban and freeway traffic data was done by combining a statistical model with a variety of indicators: local (e.g. failure messages from detectors), global (e.g. conservation of flow principle for cars) and plausibility indicators (e.g. total traffic must be the sum of individual vehicle categories).

- The local/global/plausibility indicators allow data evaluation and detection of inconsistencies and are based on combinations of different values of the traffic data sets, while also incorporating the analysis of neighbouring traffic detection sites. This is done following the theory of traffic flow conservation.
- The statistical approach is based on a general regression model, where statistical information of historical data is generated and used, therefore predicting confidence intervals for current road ranges, as well as major anomalies of the data.

Figure 7 QUATRA freeway tool – Example of visualization of plausibility indicators for freeways

Due to the differences in road network characteristics and traffic conditions (e.g. traffic flow, speed, availability of sensors), the development of the data evaluation models was conducted separately for the freeway tool and for the urban tool respectively.

The offline tool LOTRAN-DQ2, developed by Transver, was used as a base for the build-up of the tools. In the case of the freeway tool, the calculation of all indicators is done online, through the implementation of pattern matching. Figure 7 presents the graphical user interface of the software. In the top part, the road section is presented with the various detectors, while in the bottom part the indicators can be visualised.

The Transver software was also adapted for the urban tool, through the implementation of the statistical model, based on pair wise correlations. Figure 8 presents an example of visualisation of plausibility indicators for urban roads.

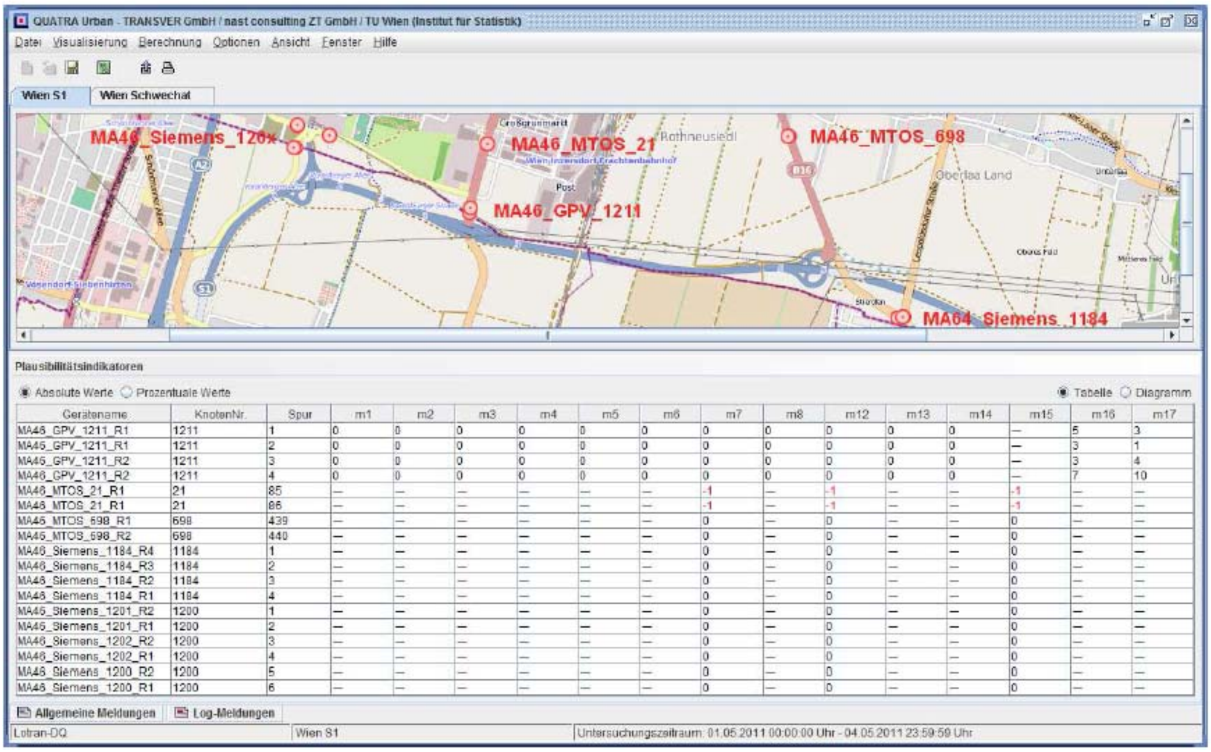

Figure 8 QUATRA urban tool – Example of visualization of plausibility indicators for urban roads

Both tools were evaluated in field trials with traffic data from Austria and Germany. The tests performed on historic freeway data showed that the freeway tool can be used to identify abnormal traffic data situations (e.g. anomalous countings). Similar results were obtained for the urban tool, which was evaluated with road traffic data from the city of Vienna. However, while the location of the anomaly can be reliably detected, further research would be needed to develop software capability of finding the reason of the anomaly.

Due to the high adaptability of the tools, transnational offline and online applications can be developed. The business concept is based on providing free versions of the QUATRA system to interested parties. The revenue would come from the installation and maintenance fees.

1.5 STEP – Short term prediction

Duration: 01.10.2011 – 30.11.2012

Budget: EUR 390.000

Coordinator: Tom van Vuren, Mott MacDonald, United Kingdom

Partners: Fileradar, The Netherlands

Katholieke Universiteit Leuven, Belgium

Eidgenössische Technische Hochschule (ETH) Zurich, Switzerland

Technische Universiteit Delft, The Netherlands

The aim of STEP was to implement and test representative solutions for real-time traffic modelling in an operational environment, for providing generic recommendations for European Traffic Control Centres (TCCs). A short term traffic prediction tool was evaluated in a real-life situation, in order to gain a better understanding regarding the potential obstacles that may arise in terms of prediction quality, data availability, technical deployment and user acceptance and provide solutions for improvement.

Objective	Outcome
Evaluation of current state of the art	Current traffic prediction tools were reviewed and evaluated to gain insight into best practices on short term traffic prediction. (see Deliverable 2, [17])
In depth insight in the needs of traffic control operators	Discussions with TCC representatives from UK, The Netherlands and Belgium, as well as online surveys were organised to understand the needs of traffic control operators, as well as the requirements for traffic prediction. (see Deliverable 2)
Development of the user interface	A web client was developed in preparation for the real-time trials. (see Deliverable 3, [18])
Calibration of prediction tool	Based on the tool already developed by FILERADAR, one of the project partners, improvements and calibration algorithms were implemented to achieve the necessary quality of prediction for high level networks. (see Deliverable 4, [19])
Implementation of the tool in a real-time trial	The prediction tool was tested at the national traffic control centre, for the region of Utrecht city, The Netherlands. Continuous improvements were added to the tool, during the trial. (see Deliverable 4)
Provision of recommendations for European Traffic Control Centres	A series of recommendations are given on how to successfully apply short-term prediction, from the perspective of user acceptance and trust, user interface, technical requirements and deployment. (see Deliverable 5, [20])

The project started by reviewing the current state of the art and looking at best practices in short-term forecasting systems, in order to identify potential gaps and to explore what are the requirements of traffic operators in terms of general applications at TCCs. A series of meetings and discussions were organized with representatives from UK, Belgium and the Netherlands, to understand more about the needs of traffic controllers in terms of functional operation and requirements for traffic prediction. Insight was gained also on predictor tools that are currently available and used.

Additionally, online questionnaires were distributed to key persons from control centres, in order to encourage them to share their views and needs. The objective was to understand the most important issues that need to be addressed when developing and implementing prediction tools, thus maximizing the potential for their application in TCCs.

The tool developed in the project was built on a short-term prediction software, already owned by FILERADAR, one of the project partners. Both the web client and prediction algorithms are written in a software environment called Dante. Due to its technology, no actual software needs to be installed in the TCC. The prediction tool can be accessed via a link in a browser. The prediction model is based on the Lighthill-Whitham-Richards model. The traffic is modelled as a fluid stream, where “bottlenecks” form regions where the “fluid” runs slowly. The model was calibrated for a large scale network, such as the one used in the pilot. Multiple calibration algorithms were developed, tested and assessed in preparation for the real-time trial.

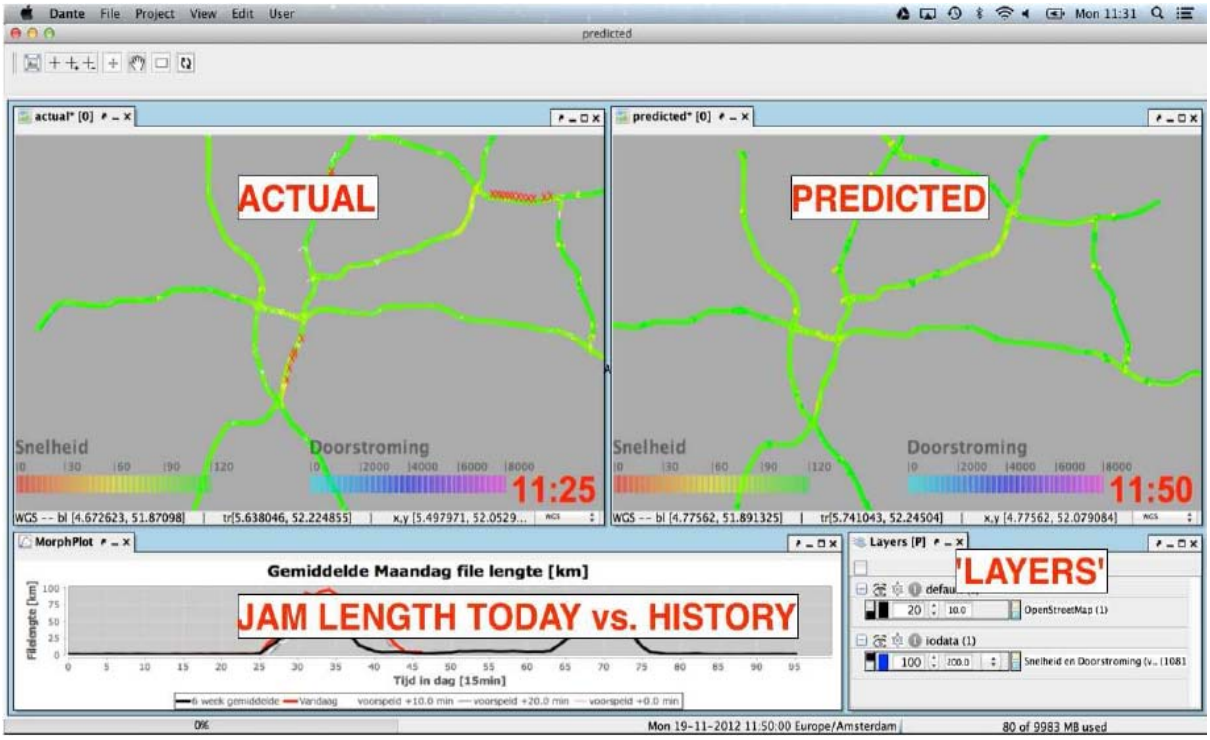

Figure 9 STEP – Web Client

Figure 9 shows the Web Client developed in the project, based on the feedback received from the TCC representatives. The traffic situation is displayed on a split screen, one highlighting the current situation and the other presenting the predicted scenario.

The project had initially planned to test the tool in two traffic centres – in UK and the Netherlands. However, due to unexpected delays and organizational complications, the planned pilot in the UK Highway Agency TCC could not take place.

The Netherlands pilot was organized at the national traffic control centre (VCNL) for the city of Utrecht and ran for four months. Figure 10 shows the network area covered by the pilot. Several improvements to the user interface and the prediction algorithms were performed during the trial, based on the feedback provided by the traffic control operators. The results of the pilot showed that short-term traffic prediction is a desired feature in a control centre. Also, the data routinely collected from standard roadside detectors and through existing communication channels was sufficient for the predictor to be developed and calibrated. The acceptance of the tool increased, as the operators had an important input in the development. However, the prediction quality was trusted only for the first 15 minutes and needs further work.

Based on the results of the trial, a series of recommendations were given on how to successfully apply short term prediction, from the perspective of user acceptance and trust, user interface, technical requirements and deployment:

- Involving TCC personnel in the implementation process of such a tool can increase acceptance; however, forming a taskforce of a few TCC operators who are enthusiastic about the idea would increase feedback levels;
- Reasonably accurate predictions on a horizon of at least 20 minutes are needed for the predictions to support the decisions made by the traffic controllers;
- Data transfer latency is critical when implementing short-term prediction tools;
- Displaying predictions on an interactive map is an efficient way for TCC staff to view the traffic predictions; also the user interface needs to update frequently, as timeliness is such an important factor;
- The use of a web client is considered an optimum method, as the client can be run on any platform and network; also updates to the software can be made quickly.

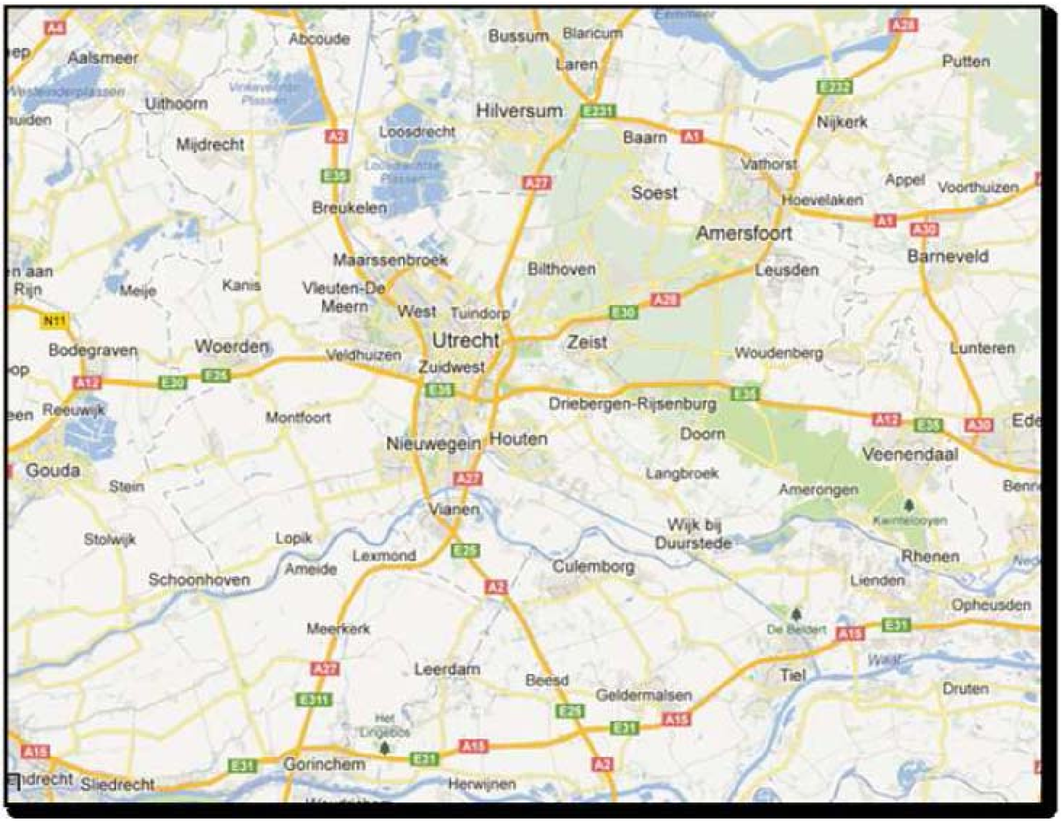

Figure 10 STEP Pilot – Overview of the network used for the NL Pilot

2 Outcomes of ENR Final Conference

At the conclusion of the programme, a one day conference was organised to present the results and overall conclusions of the five projects. The conference was held on September 27th, 2013 in Vienna, Austria and was hosted by the AIT Austrian Institute of Technology. Two parallel group discussions on the five projects were carried out, with focus on three main issues:

- Highlights: What project outcomes are considered the most important?
- Implementation: How can the project outputs be implemented in NRA activities? What are the benefits and obstacles for implementation?
- Open questions: What questions remain to be solved?

The first group discussion, focused on the projects COBRA, SEAMLESS and QUATRA was moderated by Mr Philippe Nitsche, from the AIT Austrian Institute of Technology.

The second group discussion, focused on the projects RAIDER and STEP was moderated by Mr Peter Saleh, from the AIT Austrian Institute of Technology.

2.1 COBRA

The COBRA project aimed to aid road authorities in optimally benefiting from changes in the field of cooperative systems (CS). This was done by providing an insight on the costs and benefits of possible investments, both from a societal and business case perspective.

2.1.1 Highlights and remarks

The observations on the COBRA project highlighted the applicability of the developed tool and its usability by road administrations. Some of the key remarks include:

- The tool is highly flexible; at the moment the tool is usable for UK and the Netherlands; other road authorities may provide the necessary input in the tool and use it;
- The tool calculates now the costs and benefits only for motorways, but benefits for secondary roads could be seen as implicit;
- The deployment of CS is a long term process and there are steps that need to be taken in this direction;
- An analysis of the legal issues that influence the deployment of cooperative systems was performed in the project, so each road authority needs to look at its own situation and decide what to do;
- While the NRAs are the main stakeholders for COBRA, other stakeholders could take advantage of the tool;
- The usability of the tool could increase, by giving the stakeholders the option of adapting the tool to their specific needs.

2.1.2 Implementation steps

In terms of implementation, the NRA representatives stressed the importance of having the option of applying the tool to various situations and scenarios:

- Various improvements could be implemented in the tool by having the possibility of looking at individual systems and applications, rather than bundles;
- A concern was raised regarding the availability of systems in different countries and also the usability of the tool at a trans-national level with several NRAs involved;
- While the tool produces an overview of the costs and benefits for the road authorities, there is the need to look at business cases that involve also other parties;
- For the success of the implementation, a maintenance and management service should be provided for the tool. This service would integrate new developments such as new functions, new business cases, or making the tool more adaptable to geography conditions, not only at country level but also at a trans-national level.

2.1.3 Open questions

The following open questions remain:

- Who will take over the future management and dissemination of the tool?
- Who should be in charge of this procedure? What about the costs of maintenance and integration of further developments?

2.2 SEAMLESS

The aim of the project was to achieve seamless dissemination of data in urban and inter-urban networks through harmonized data protocols. The development and implementation of new technologies (e.g. cooperative systems) will bring new sources of data, new end users and new communication channels.

2.2.1 Highlights and remarks

The remarks on the SEAMLESS project focused on the applicability of the generic architecture on various use cases. The main highlights include:

- The developed architecture serves as a baseline, as a common base of data exchange between various systems; it is a global view on the communication between parties;
- The main stakeholders are road authorities and service providers, but the benefits are indirect; the benefit is to provide a better harmonisation between different methods of traffic management, between different legacies;
- By identifying and selecting a specific use case, a specific part of the architecture can be used (as the communication chain);
- The concept is not to develop something new, but to reuse the existing standards for a specific use case;
- For the two use cases presented in the project, the DATEX II profiles are ready and usable.

2.2.2 Implementation steps

Regarding implementation, the architecture provides a basis, as presented in the project:

- Each NRA needs to look at its own scenario and based on the generic architecture, to adapt to a specific situation;
- There is a need to encourage the road authorities to use the guidelines for deployment scenarios provided in the project;
- The next step is to present the results to a standards group;
- The profiles (DATEX II) modified for the two use cases presented in the project, are ready for use;
- For the practical implementation, a software company would need to be employed to implement the profiles.

2.2.3 Open questions

The following open questions remain:

- How to apply the generic architecture to other use cases?
- What is the role of various involved parties, in the communication chain described in the architecture?
- What is the role of the roadside ITS stations, as they always want to have the logic in their systems?

2.3 RAIDER

The focus of project RAIDER was to improve incident detection on motorways and secondary roads by incorporating novel technologies such as roadside and in-vehicle systems and nomadic devices.

2.3.1 Highlights and remarks

The main observations on the RAIDER project focused on the feasibility of novel technologies, assessed in the study. The main highlights are:

- The generic specifications developed can help NRAs make an informed decision on what are the best technologies for incident detection, according to their needs;
- The quality of incident detection is a question of accuracy of time and location;
- Therefore, new technologies that provide new sources of data have to be reliable;
- The trend is to make the most out of the existing sensors, while also promoting new technologies, such as cooperative systems, which could provide additional information about the road infrastructure, traffic and weather conditions;
- A well-defined combination of different technologies, like nomadic devices plus eCall will be the key figure for the next couple of years towards 2020;
- The penetration rate of novel technologies is essential for the improvement of incident detection.

2.3.2 Implementation steps

The project delivered generic specifications for comparing novel technologies and they can be used directly by national road administrations, through these steps:

- Look at the existing situation: type of road network, traffic flow counts, available detection sensors, etc.;
- Identify the requirements for the desired situation: depending on the type of incident and the performance requirements needed for optimum detection;
- Look at the options for incident detection systems: based on the requirements, choose the novel technologies that would best suit incident detection;
- Perform an assessment of system configurations: based on the methodology developed in the project, an assessment of the selected technologies can be performed;
- An obstacle towards implementation is the clash between road authorities and car manufacturers, regarding who should first start the implementation;
- It is important to determine a basic set of settings for the novel technologies that will be implemented in the future, as there is a need for harmonisation and system compatibility.

2.3.3 Open questions

The following open questions remain:

- How to bring car manufacturers and road authorities together in the implementation process of novel technologies?
- What are the costs and benefits that will come with the implementation?

2.4 QUATRA

The main objective of the QUATRA project was to develop procedures and software tools for the quality evaluation of traffic data on freeways and urban road environments.

2.4.1 Highlights and remarks

The discussion on QUATRA focused on the applicability of the tools developed during the project:

- The freeway online tool is ready for the market and can be implemented in TCCs;
- The offline tool is also ready, but still needs evaluation;
- The main benefit of the tool is the reduction of time and costs of identifying the location of a problem, even though the reason is not yet known;
- The tool is able to use multiple sources of data (e.g. inductive loops, tolling systems) for the calculation of the quality indicators;
- The tool can be used by road operators, maintenance engineers as well as for statistical purposes.

2.4.2 Implementation steps

Regarding implementation, the versatility of the tool was discussed:

- The freeway tool is ready for the market and available free of charge and revenue will come from the installation process and maintenance in TCCs;
- As each country has its own sources of data and data formats, the software will need to be adapted to the specific situation of a traffic control centre;
- The end users of the tool are the road operator (which can use the online tool in real time) and the maintenance engineer (the data is calculated at night and reviewed afterwards);
- In addition, the tool can be used for statistical purposes, by identifying the anomalous data and flagging it; therefore the erroneous data will not be used at the end of the year for the purpose of traffic data statistics.

2.4.3 Open questions

The following open questions remain:

- What type of technology provides the most usable data?
- How to connect different quality indicators, for a more proficient end information?
- How to make the tool more efficient and more user-friendly?
- How to connect the tool with other systems that can provide more information, therefore having a harmonised display of information? (E.g. link to construction sites data – overlapping the tool with a road works management system)

2.5 STEP

The aim of STEP was to implement and test representative solutions for real-time traffic modelling in an operational environment, for providing generic recommendations for European Traffic Control Centres (TCCs).

2.5.1 Highlights and remarks

The discussion on STEP underscored the importance of working with the end user in mind:

- Short-term prediction can be used not only for monitoring and foreseeing the next 15-30 minutes of a traffic situation, but also for a more efficient traffic planning (e.g. by using historical data);
- Testing the application in an operational setting is an optimum method of finding out the needs and requirements of traffic control operators;
- The direction is towards avoiding work overload, as the operator has already a multitude of screens to survey at all times;
- The amount and type of data that is routinely collected from standard roadside detectors and through existing communication channels is sufficient for the predictor to function.

2.5.2 Implementation steps

The successful implementation of the tool depends on multiple factors:

- The engagement of operators in an early stage of the planning process is important, not only for receiving feedback, but also for increasing the acceptance of such an application;
- Integration of the tool in the already existing systems of TCCs must be done in such a manner that it does not increase workload;
- A possible mitigation could be to implement the application so it does not have to be reviewed continuously, but rather send alerts when needed;
- It is important to get end users informed regarding what can be achieved by prediction, thus increasing the trust in such a system.

2.5.3 Open questions

The following open questions remain:

- How to integrate and combine different tools existent in the traffic control centre, in a way that the operator can benefit the most and traffic management is improved?
- What additional information should be offered?
- What happens if the system fails?

3 Conclusions and recommendations

ERA-NET ROAD II aimed to strengthen the European Research Area in road research by coordinating national and regional road research programmes and policies. The overall aim of the trans-national joint research programme **ENR 2011 "Mobility – Getting the most out the Intelligent Infrastructure"** was to improve the management of the European road network.

As road administrations face important investment decisions in the future regarding the purchase of intelligent infrastructure, the focus of the programme was on identifying the challenges faced by national road administrations in embracing new infrastructure technologies. The research aimed to improve the implementation of Intelligent Infrastructure, by identifying feasible, valid and cost-effective solutions for key European roads, which will enable road administrations to determine where to target resources to obtain the best value.

The ENR Mobility initiated projects focused on concepts such as impact assessment of intelligent transport systems (COBRA), effective distribution of road authority data (SEAMLESS), high quality traffic management data (QUATRA), incident detection (RAIDER) and implementation of short term prediction (STEP).

The tools, models and methodologies developed in the five projects will provide road authorities with the necessary knowledge on:

- Which cooperative services deliver maximum benefit and enable road operators to manage road networks more cost-effective;
- What are the prerequisites for seamless use and distribution of traffic data to third parties, such as service providers and in-vehicle devices;
- How to evaluate the quality of traffic data and mitigate the associated risks of erroneous data on motorways and urban road environments;
- What are the requirements to improve traffic incident management, as well as the novel technologies that could help decrease the overall costs of detection;
- What are the requirements needed for the implementation of a real-time modelling tool in a traffic control centre, from the technical aspects to the user interface and user acceptance.

Benefits of the Programme to NRA stakeholders

More emphasis needs to be put on the implementation aspects of the results. Although each project in itself had an implementation/dissemination plan, there is no programme strategy on how to proceed with the results. There needs to be a concerted effort to ensure that the tools, recommendations, generic specifications and models are used across CEDR member countries.

The tool developed in **COBRA** has already been received very well by the stakeholder representatives at the final conference, who pointed out that the tool can be highly useful in developing an ITS plan for 10 years. Another remark was that the tool could be used at a European level, for the EasyWay Cooperative Corridor. Further improvements in the future could help make the tool a key piece in the assessment of strategies at a national and European level.

Similarly, the **RAIDER** generic specifications can be used by different road administrations to make informed decisions on what are the best technologies for improving incident detection. While the methodology is generic and does not refer to a specific cooperative service or product, it can provide a better insight in the balance of costs and benefits for achieving optimum incident detection.

Although the applicability of the **SEAMLESS** results cannot be seen immediately, the DATEX II profiles prepared in the project are ready to be used. It is the recommendation of the project coordinator that road authorities take the standard profiles and use them. In addition, the generic architecture serves as a basis for development of further use cases and can help NRAs have a better insight in how to move from roadside infrastructure to mobile (in–vehicle) information distribution.

The results achieved in **QUATRA** can be used and implemented as they are. The offline tool used as the basis for the development of the QUATRA tools is already used by the German Road Authorities, free of charge. Therefore, the benefit for NRAs has already been proved. The multiple use of the tool (e.g. statistical purposes, monitoring of operations and reconstruction of traffic situation) is also an advantage and can bring benefits. Due to the high adaptability of the tools, further trans-national offline and online applications can be developed and applied across CEDR countries.

STEP showed what the requirements for the implementation of a real-time prediction tool are and how it can help traffic operators in their daily operations. The purpose of the tool includes traffic management measures, such as monitoring and reviewing the network (e.g. cutting off a lane, mitigating an accident, open/close hard shoulder). The predictive capability is of increasing importance, as there is a great interest in the “what-if” scenario, i.e. looking into the future and knowing what to expect.

As the joint research programme comes to an end, some general recommendations can be given:

- More emphasis needs to be put on the implementation aspects of the results;
- The results (tools, models, specifications) should be disseminated across CEDR member countries;
- Active involvement of NRA stakeholders is crucial to any research project, as they are the main benefactors;
- More interaction between the projects would be valuable and would help enhance the results;
- The outcomes of the joint programme should be used as a basis for further research work.

The ERA-NET ROAD concept encourages the exchange of knowledge between National Road Administrations in Europe and gives them the opportunity to improve the quality of European roads, while reducing costs. Through this programme, tools and procedures were developed on how to cooperate internationally on various topics and projects. The success factors were trust (between the partners), understand (what are the relevant topics) and commit (through funding and dedication). The joint programme ENR “Mobility – Getting the Most out of Intelligent Infrastructure” has been a success, as it included a number of European countries as project partners, but also addressed research areas of common interest and of great importance to all road authorities across Europe.

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Abbreviations

AIT	Austrian Institute of Technology
CEDR	Conference of European Directors of Roads
CEN	European Committee for Standardization
CBA	Cost Benefit Analysis
COBRA	Cooperative Benefits for Road Authorities
CS	Cooperative Systems
ERA-NET	European Research Area Net
ETSI	European Telecommunications Standards Institute
FEHRL	Forum of European National Highway Research Laboratories
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
NRA	National Road Administration
OTS	Open Traffic Systems
QUATRA	Software and Services for the Quality Management of Traffic Data
RAIDER	Realising Advanced Incident Detection on European Roads
SEAMLESS	Seamless Traffic Data Dissemination across urban and inter-urban Networks
STEP	Short Term Prediction
TCC	Traffic Control Centre
TMC	Traffic Management Centre
TNO	The Netherlands Organization for Applied Scientific Research
TPEG	Transport Protocol Experts Group
TRL	Transport Research Laboratory
UTMC	Urban Traffic Management and Control
UK	United Kingdom