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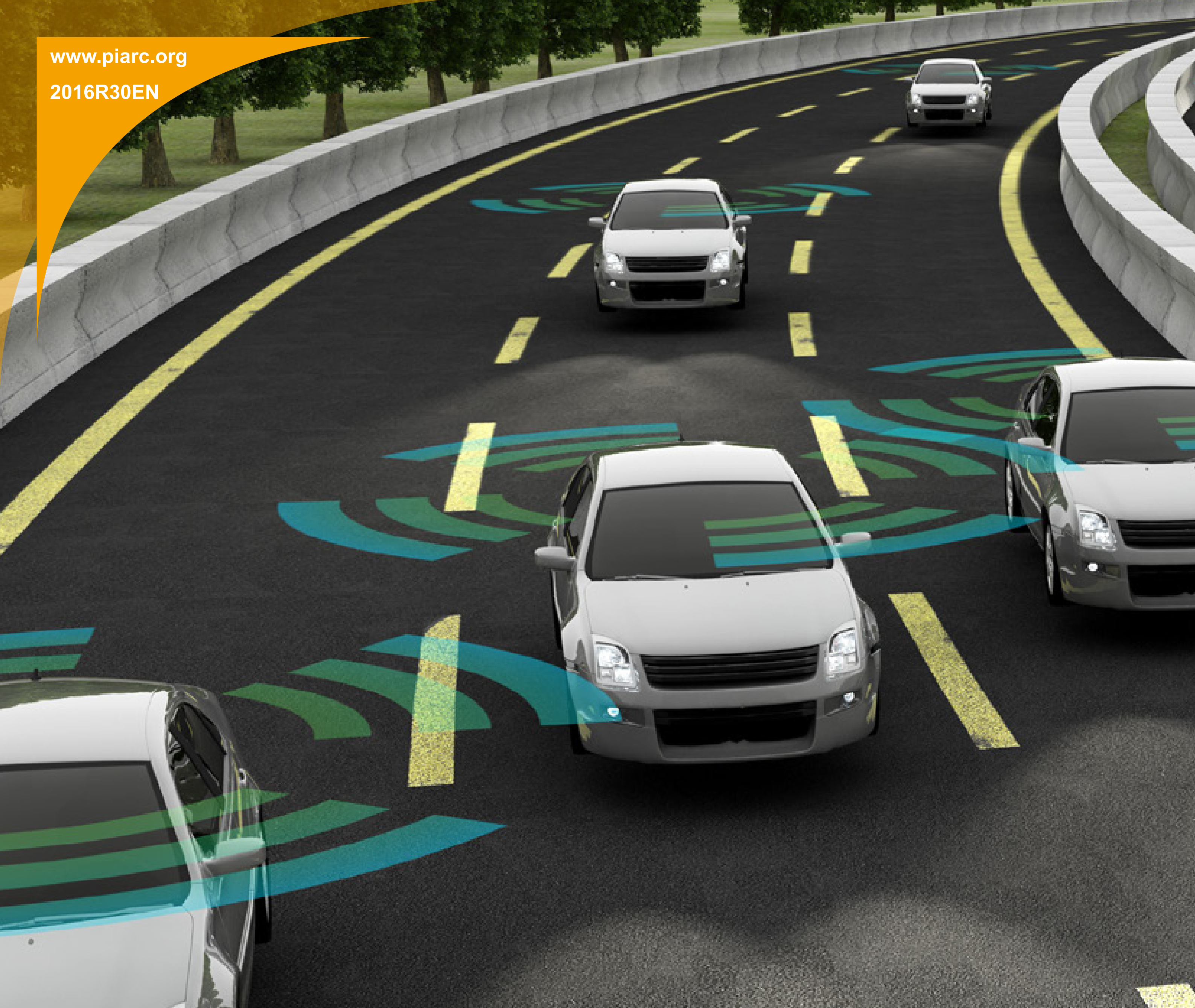

ADVANCED TECHNOLOGY FOR DATA COLLECTION AND INFORMATION TO USERS AND OPERATORS

Technical Committee 2.4. *Winter service*
World Road Association

STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2012 – 2015 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were nominated by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

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2016R30EN

ADVANCED TECHNOLOGY FOR DATA COLLECTION AND INFORMATION TO USERS AND OPERATORS

The study that is the subject of this report was defined in the PIARC Strategic Plan 2012-2015 approved by the Council of the World Road Association.The report provides brief summaries of projects from around the world, presented in the form of use cases that are representative of innovative ways of collecting, distributing, and making use of mobile data to assist transportation officials in their winter maintenance operations and to provide information to the traveling public. The use cases or case studies were selected because it is the belief of the authors that, when deployed, any of the technologies described will have a positive impact on transportation safety, mobility, the environment, and/or more efficient use of human and material resources needed to carry out their winter maintenance duties. As an added bonus, these use cases generally result in the traveling public being better informed, which results in them making better travel choices and being more accepting of the technologies.

CONTENTS

1. INTRODUCTION

The terms of reference of strategic theme 2 for the cycle 2012-2015 underline the interest of the World Road Association in encouraging the improvement of access and mobility provided to the community and industry by improved road network operation and integration with other transport modes. At the heart of this issue is the need to provide services in a predictable manner and to ensure that the resilience of the network is set at an appropriate level.

Road networks are particularly vulnerable to the adverse effects of winter weather and maintaining acceptable levels of service in the light of budget cuts during sustained snow events or slippery situations can be particularly challenging. Issues such as sustainability and climate change must also be considered and the provision of appropriate data to road users is vital.

The use of advanced technology for data collection and provision of information to users and operators is a way to ensure the resilience of the road networks in winter.

The strategies selected to achieve this report are described below.

Investigate innovative approaches for data collection and information to users and operators for the purpose of safer winter operation, with particular focus on vehicle-based technology. Advanced technologies are being developed and deployed on mobile platforms to collect data regarding the roadway environment and transmitted to operations centers to help make tactical decisions during winter events. These data are also available to support advanced traveler information systems to aid road users during winter storm events. From case studies investigate applications and deployements of these advanced technologies to show the feasibility and utility of these systems.

The collation of the case studies or use studies was organised as described below:

- Conduct a literature search
- Define and find case studies from member countries
- Conduct interviews of subject matter experts
- Compile case studies in a technical report to form part(s) of the association´s knowledge-base

Increasing knowledge about the pavement surface condition and the roadway weather environment gained through real-time data collection has created opportunities to make better decisions and automate portions of winter service programs. The winter maintenance community is not the only group gathering data. Transportation operations managers have also been creating systems to help operate the transportation network and improve safety of travelers through Intelligent Transportation System (ITS) deployments. The data can also be of value to winter service providers. This paper presents general technological trends in the field and a few "*use-cases*" that PIARC's Technical Committee 2.4.3 "*Advanced technology for data collection and information to users and operators*" considers good examples of efforts around the globe involving innovative ways to collect, process, and utilize weather-related data for winter maintenance purposes. The study covers a scope of mobile vehicle based data (intrinsic, as well as from additional on-board devices), useful for road winter applications

In recent times, we have seen the needs and efforts of traffic managers and winter service providers converging and providing opportunities to deploy technologies that address the needs of traffic managers (to manage traffic flow), winter service providers (winter maintenance support systems) and the users of the transportation system (improved mobility and safety).

Generally speaking, data sources have been from discrete, physically fixed sensors. These include Road Weather Information Systems (RWIS), Environmental Sensing Stations (ESS), speed and vehicle classification sensors, and video surveillance. Improvements in cell phones, communication (backhaul) systems, GPS location systems and sensor technology have created opportunities to deploy mobile data gathering platforms that can vastly complement the stationary data collection systems used by transportation officials; at the same time, these systems can help convey information directly to a user or provide needed data to the user's vehicle. Mobile data collection platforms provide an opportunity to fill-in the gaps between fixed stations and to collect data from a greater operational area, allowing for the targeting of specific areas of concern.

In considering vehicle-based technologies, data can be obtained from a variety of vehicle-based sensors. The hardware and software needed for gathering data from mobile platforms and the transmittal of the data to land based systems, is collectively called vehicle to infrastructure (V2I) systems. Mobile data can originate from the vehicle's native sensors, from sensors retrofitted to the vehicle, or even from mobile RWIS systems. Alternatively, when land based applications or systems transmit data or information directly to a vehicle or to some device users may have in the vehicle, the process is referred to as Infrastructure to vehicle (I2V) systems. The third scenario occurs when data from vehicles is transmitted directly to other vehicles, in near real-time; these are referred to as vehicle-to-vehicle (V2V) systems.

Applications utilizing data gathered from vehicle based technologies can result in winter service improvements through more timely data inputs into Winter Maintenance Support Systems (WMSS); thus allowing transportation officials to be more responsive to deteriorating weather and pavement conditions, with the added advantage of being able to directly transmit location-specific treatment recommendations to the snowplow operators. Additionally, user-relevant road condition data gathered from vehicle based systems can be advantageous for selecting appropriate routes, selecting mode choices, delaying or postponing trips, with likely improvements in safety and mobility. Many countries are working on these applications and have made deployments either to evaluate the vehicle-based technologies or to create operational efficiencies. Use of vehicle based data has a huge and still underestimated potential for road winter maintenance. The use cases presented in the body of this report are examples of how transportation officials are taking advantage of technological improvement on mobile data collection and transmission and how they are using that data to optimize the transportation system' safety and mobility, while reducing adverse impacts on the environment.

2. WINTER MAINTENANCE PROBLEMATIC

The concept of winter service can be defined as "*the resultant of various actions and provisions, taken by all the actors, to adapt or fight the direct or indirect consequences, of the phenomena that negatively impact on road traffic in winter*".

During a winter storm snow and ice can produce deteriorating road conditions that have a negative impact on road users and traffic flow; extending travel times or even making roads impassable. To limit or avoid the effects of a winter snowstorm, several types of actions are possible:

- Restore or maintain road conditions to permit free flowing traffic. These actions, which include standby, monitoring and treatment, make up winter maintenance.
- Inform road users of current road conditions and how the conditions may change to encourage them to adapt to changes in driving conditions..
- Implement traffic management measures to suit the current or predicted conditions..

We can see that behind these actions there is a whole raft data and information made up of knowledge, skills, records of actions, weather and climate information and levels of service that is available to be shared to improve winter service.

This report reviews a limited number of technologies that either directly impact on data collection and information sharing for winter service or can be adapted for that use. It is expected that in the future the use of these technologies will be widespread. The case studies in this report are summarised below.

Cooperative ITS corridor joint deployment (Western Europe, NL-DE-AT) is an interesting cross-border deployment of ITS, initially to warn drivers about road works, but also to collect data from vehicle probes that can enhance winter service.

MOBI-ROMA is a tool initially envisaged for the maintenance of the roads, but the data-gathering can also be used to determine the degradation of surface qualities in wintry situations. The emphasis of the study is on road surface condition monitoring using data coming from vehicle's internal sensors through the CAN-bus, (floating car data) or simple devices mounted on the vehicle. Similar techniques with suitable sensors can be used also for assessing strength of road bed or need for winter maintenance.

Mobile µTEC road surface state sensor as verification for a winter maintenance The strategy developed in this case study concerns the determination of the road surface conditions on wide road network using mobile devices to optimize winter maintenance actions.

ROSTMOS: Intelligent Transportation Systems (ITS) technologies such as Road Weather Information Systems (RWIS), automatic vehicle location (AVL), other vehicle-based monitoring systems and connected vehicles hold enormous potential for making winter operations and driving on winter roads more efficient. All this information can be used to make the optimum decisions to restore road conditions during winter events.

Bluetooth Sensors Use, not specific to winter service, this device allows the time travel acquisition which is an interesting data for the winter maintenance team in charge of the snow removal or salt spreading.

Using Vehicle Sensors to Understand Driver Behavior, this very open approach allows the monitoring and reporting of dangerous road conditions in real time to warn drivers in the vicinity to avoid accidents. This is particularly interesting when degraded winter road conditions occur.

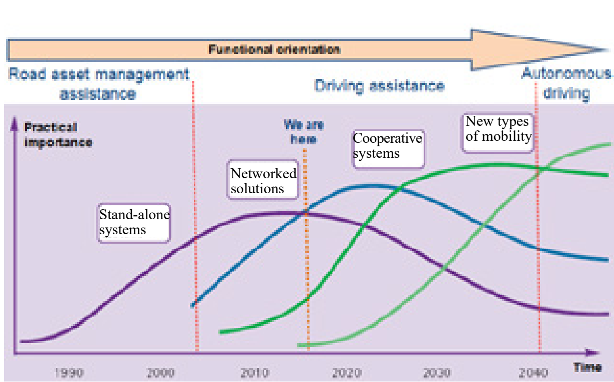
5.9 GHz Dedicated Short Range Communication Vehicle-based Road and Weather Condition Application: the expectation is that the additional weather information collected from mobile platforms (winter maintenance trucks), in conjunction with the more traditional sources of weather and transportation-related information/data, will enable traffic managers and maintenance personnel to implement operational strategies that optimize the performance of the transportation system by mitigating the effects of adverse weather.

Nevada Department of Transportation's Integrated Mobile Observations Project : this project uses on-vehicle instrumentation to dynamically gather near-real-time localized weather, road condition, material usage, and vehicle-related data that will be used to gauge road conditions and better inform safety processes (such as chain controls) by providing this data to supervisors and operators through mediums.

3. TECHNOLOGIES AND TRENDS

Rapid and even more growing development of widely applicable information and communication technologies (ICT) in the last decade provides new and never existing before opportunities for road transport. The main potential here arose from availability of new type and huge amount of scattered mobile data, which are to be used for various purposes. The modern paradigm of Intelligent Transportation System (ITS) defines it as an effective interaction of many different elements, providing proper data flow for certain services, also road winter maintenance related (f.i. MDSS (Maintenance Decision Support System) , traffic information and adaptive management accordingly to actual pavement conditions a.o.). In this context, the road transport sector may benefit from use of “*Big data*”, which are represented by a variety real-time mobile probes, embedded or linked to vehicles. Hereby, “*Big data*” is a conceptual approach, describing the exponential growth and availability of data, both structured (accurate and dedicated, as from RWIS and network management) and unstructured (also indirect and anonymous, as from vehicles). More data may lead to more feasible analyses and more confident decision making, which means greater operational efficiencies and cost reductions.

Having autonomous driving as a long-term target, the industry is gradually going through the corresponding development phases (*illustration 1*), where communication (connectivity) between vehicles and infrastructure becomes a key factor. From the other side, fast penetration of such technologies to fleet (especially to ordinary vehicles) by means of conventional or mandatory vehicular equipment, provides higher reliability of data models and more added values for related services (*illustration 2*). That is why international institutions and national public authorities now try to put regulations in the ITS field to foster harmonized development here.



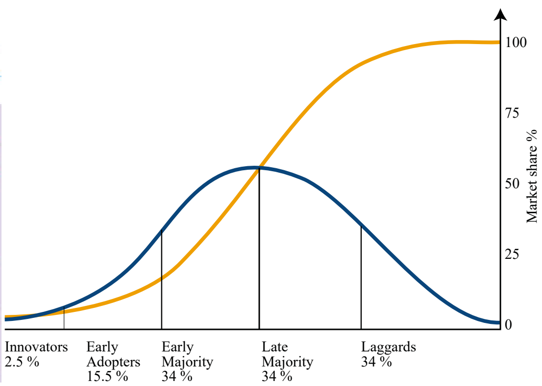
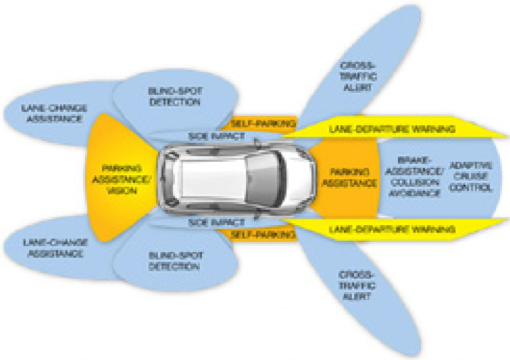


Illustration 1. – general direction of ITS development /
Illustration 2. – penetration graph of new technologies

The automotive industry provides an even higher level of vehicles automation with constantly growing amount of embedded sensors and subsystems for traffic safety and operational control. Some of them are of advisory nature, providing assistance for drivers and registration of operational parameters, however, the vector of technological development now is moving towards adaptive solutions, providing full-fledged autonomous reaction algorithms of vehicles in critical traffic situations (*illustration 3*). Three main sources of mobile data from conventional modern vehicles are identified, as following(*illustration 4*):

- mandatory intrinsic system (in-built electronic control for the main operational parameters of engine and other functional subsystems of vehicle):

- existing on-board sensors (mainly for driving assistance, f.i. precipitation detector) ;
- nomadic or optional in-built devices (smartphones, navigators a.o., which are able to fix vehicles' tracking and acceleration).



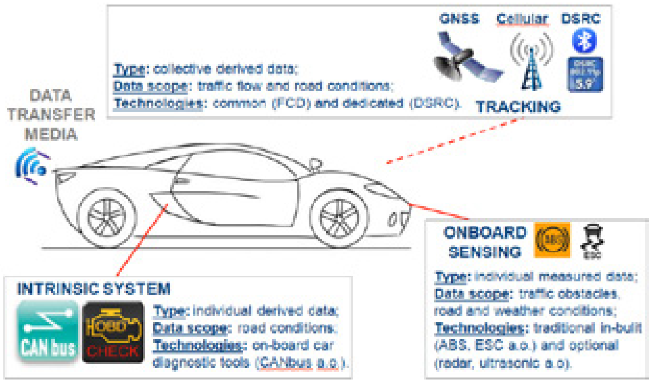


Illustration 3. – driving assistance tools / Illustration 4. – common data sources

There is principal data flow for such solutions, where data is processed through predefined interface (f.i. OBDII for intrinsic system) and may fit common ITS platform through a range of V2V and V2I communication interfaces. However, there are also raw technologies, where data reliability and interpretation is needed to be continuously tested and standardized. There still exist significant societal barriers, such as aspects of personal data use, therefore pilot projects usually cover only specific fleet, where the number of mobile probes is strongly limited and legally approved

In spite of still existing constraints of vehicular data use, certain floating car data (FCD) solutions boosted on the private sector's provided platforms. The trend is: some global IT companies provide web mapping and interactive traffic navigation services for free, but their users allow to be tracked, providing network-wide real-time traffic pattern. Social media also can be added there to have direct feedback (notifications, comments a.o.) from road users on traffic events (*illustrations 5 y 6*).

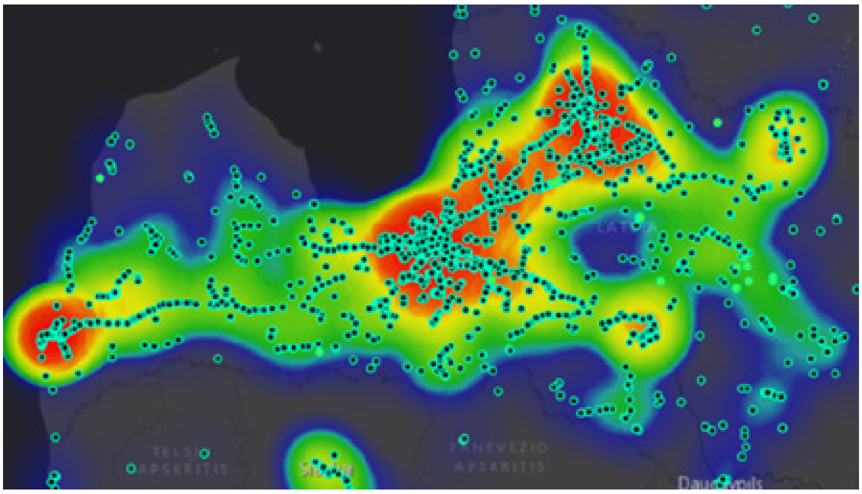


Illustration 5. -
Heatmap af events in operational environment

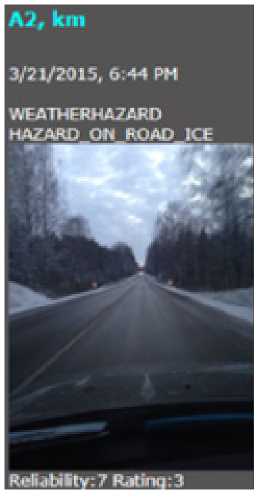


Illustration 6. -
Details of the event

Unlike classic roadside monitoring devices, that are valid only for very accurate spot measurements, vehicles as active and mobile sensing units allow the capturing of a variety of corresponding data across the whole road network in a cost-effective way. Concerning specific needs of road winter maintenance, meteorological and pavement conditions (in many cases characterized indirectly, f.i. current status of windshield wiper or activating of anti-skid devices), captured by on-board systems of moving vehicles are of particular interest, as additional input to decision-making support tools and traffic information services (*Illustration 7*).

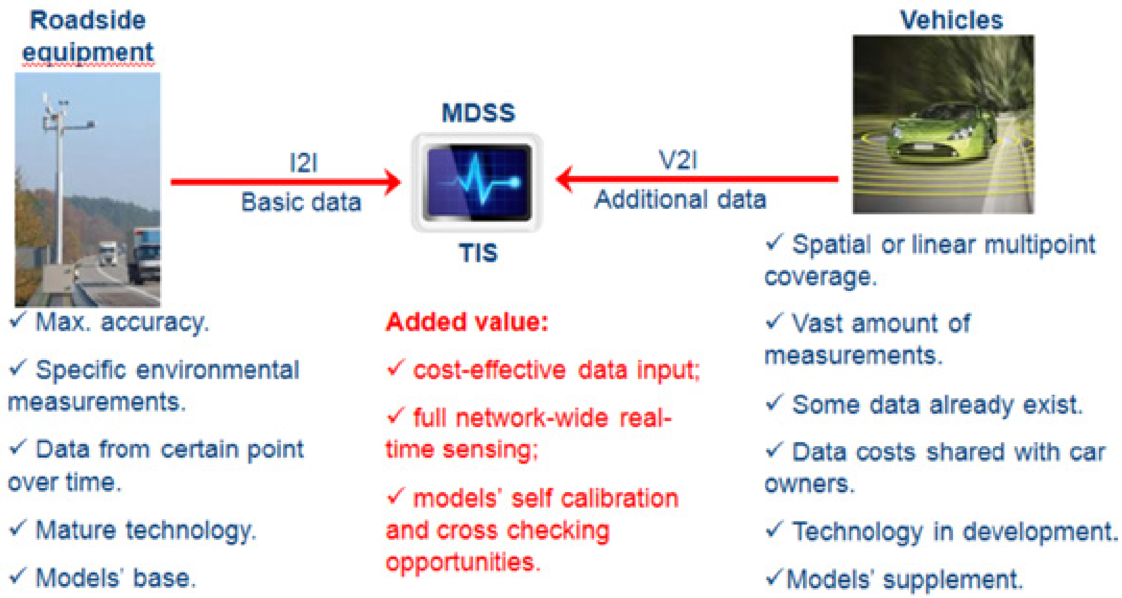


Illustration 7. Vehicle based data aspects for winter road applications

The report reveals and summarizes eight notable case studies,representative of the current state of the art, on vehicle- based data use in the field of road winter maintenance from Europe and North America. Major findings here are:

- Most mobile data is being sourced from special fleets (taxis, spreaders, public buses a.o.) due to simple and uniform access to data;
- Mobile data shows well a correlation with the context, but need to be interpreted more precisely (sophisticated data models);
- Various practical and effective interfaces for mobile data transfer between vehicles and infrastructure already exist;
- Mobile data acquisition from ordinary vehicles calls for legislative measures and broad partnerships.

4. CASE STUDIES

The following chapters present the selected eight use cases. The use cases were selected by a working group in PIARC's *Technical committee 2.4.* All group members have provided one use case from around the world, mostly from Europe and US.

Each use case is described based on the same issues and is introduced by a short summary in a "*Short Fact box*". The purpose of this "*short fact box*" is to give the reader a quick glance of the use cases and give the reader information such as status, time frame, owner, participants and contact information.

Each sub-chapter describes one use case with a structure based on:

- Description of issue or technology gap
  This section describes the issue and the problem which have initiated the project.
- Solution – satisfaction of the need
  Briefly describes the type of solution to close the technology gap.
- Data quality
  Describes how the quality of data is ensured.
- Managing data
  Describes how the data is processed, sorted, collected and stored; gives an understanding of ownership, sharing and financial agreements.
- Benefits for infrastructure manager / Road operators
  A view of the benefits to the infrastructure manager or road operator by using this type of technology.
- Benefits for road users
  A view of the benefits for road users.
- Institutional issues or challenges
  Describes the institutional issues or challenges which have to be solved for a successful implementation.
- Lessons learned
  Higlights lessons learned from their particular experience for others to take into account when considering similar deployments
- Future works
  Refers to additional work related to the use case or to the subject overall.

4.1. COOPERATIVE ITS CORRIDOR JOINT DEPLOYMENT (WESTERN EUROPE, NL-DE-AT)

The project is an initial full-scale implementation of "*Day one*" C-ITS services at a pan-European level. Transit corridor Rotterdam-Frankfurt/M.-Vienna (included TEN trans european network) is selected for two pilot services: 1. roadworks warning from the traffic controls centers via the roadside infrastructure to the drivers; 2. probe vehicle data from vehicles transmitted to roadside infrastructure and the centers, which can provide valuable dynamic input also for road winter maintenance.

Status: the project is ongoing and its first phase was scheduled to be operationally launched for users in mid of 2015.

Time frame: The memorandum of understanding between partners was signed in 10.06.2013., but the end of 2015 was set as the deadline for preparation of the centers and road infrastructure.

Owner: national road operators of NL, DE and AT are the main stakeholders, providing investments in project's hardware. In fact, the countries realize three parallel national projects, related to upgrade of their route's parts upon the agreed technical criteria.

Participants: Taking into account project's key role for gradual rolling out of C-ITS services in Europe, the European Commission is its observer, looking for further legislative initiatives. A broad strategic alliance "*the Amsterdam Group*" is involved there for advisory purposes, which involves representatives of professional umbrella associations: European road administrations (CEDR); toll road operators (ASECAP); cities (POLIS); automotive manufacturers and associated industries (Car2Car).

Contact information: "*the Amsterdam Group*" (e-mail: info@amsterdamgroup.eu; web: *www.amsterdamgroup.nl*).

Website address/links: there is no dedicated web site for the project. Only a short description is available in web. No project documentation is identified for public access. It seems, there are no ongoing PR activities related to the project.

4.1.1. Description of the issue or technology gap

The project is a proposal of structuration for C-ITS pilot deployment after a decade of R&D activities for V2X communication technologies and it is based on a number of predecessors and field operational tests. The main idea is initial deployment of basic C-ITS services (that already have functional prototypes in the ITS spheres) which can be tested in practice and then be gradually succeeded by more complicated efforts and expanded on a broader infrastructure. Actually, all project-related technologies exist and most of them are quite mature (e.g. which are standardized and have industrial solutions for market).

4.1.2. Solution –Satisfaction of the need

V2I and V2C communication will be realized through hybrid platforms of DSRC (Wifi 802.11p; 5.9Ghz) and the cellular network (3G; 4G), (*illustration 8*). V2V will not be established (as more complicated). Road operators must provide high speed communication backbone for I2C and wireless access points V2X for stretches, where telecommunications doesn't exist. Concerning probe vehicle data collection, there is still uncertainty about its scope. Definitely, it should be much broader than such of already existing floating car data methods. Taking anonymous data from all the fleet is possible through not only in-built, but also nomadic devices, giving access to vehicles' intrinsic data more, than relying on some specific on-board sensors (as it is usually for R&D and on specific fleet oriented projects).

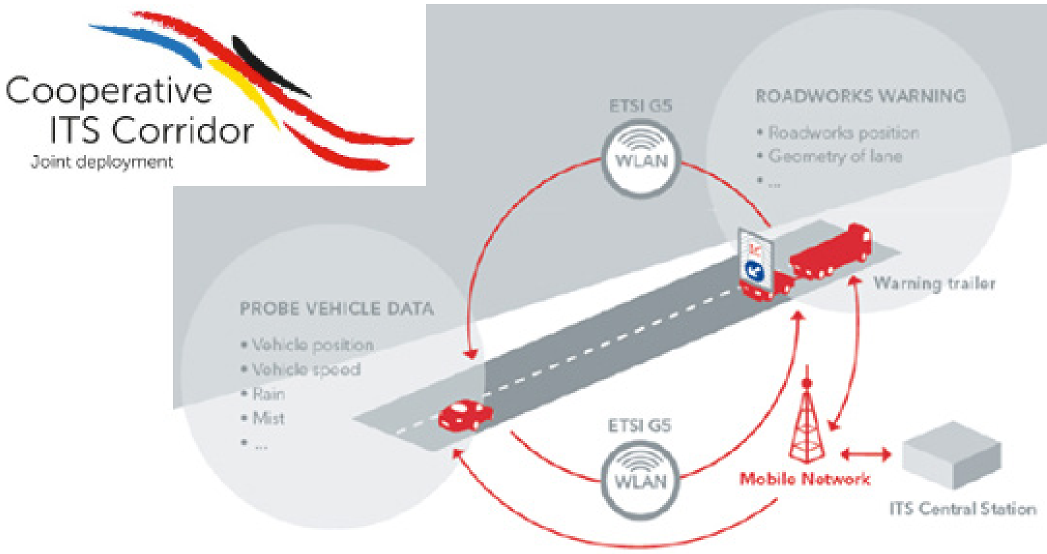


Illustration 8. Project's functional description

4.1.3. Data quality

Guidelines on key performance indicators for traffic data gathering (scope and quality) and sharing (accessibility and compatibility) at the EU-level already exist. According to EU ITS Directive 2010/40/EU, there will not be strictly prescribed data attributes for EU-wide harmonized ITS services, but only functional specifications, which are binding for 26 EU member states and associated partners. So instead of excessive requirements for raw data, traffic announcements' description must be identical. For instance: dangerous driving condition messages could be interpreted differently in Italy, Sweden and Latvia, but when they conform to a general methodology or standard and are being applied for a common purpose, traffic information messages, for example, they should be universally understood.

4.1.4. Managing data

Data handling for roadworks warnings (as a principal model of many other categories of traffic restrictions) is provided separately by each road operator, but data sharing and compatibility on C2C level will be reached, using DatexII (subtype of XML protocol for traffic data coding in Europe). EU legislative measures aim to find open space for related data, e.g. data holders must provide them accessible to other actors through DatexII nodes of their data systems, without any specific agreements. Probe vehicle data is still uncertain part of the project. Taking into account that, under the current project's scope, these data will not provide immediate feedback to the drivers, it is assumed that authorities will store it and analyze it in the future. The needed metadata of road transport is already available (EU INSPIRE Directive). Primary traffic data holders are responsible for all the related data aspects (costs, procedures, etc.), but some external investments (EU co-financing)is available only for service-harmonization purposes.

4.1.5. Benefits for infrastructure manager / road operators

Road operators will benefit from a vast amount of online data coming from moving vehicles, which can be processed and fused for many road management purposes. Concerning road winter maintenance, these data may provide significant added value to MDSS, roadworks' quality control and for the next generation of traffic information services, having positive effect on: direct costs, operational timing, performance control and road users' satisfaction (through higher level of traffic safety).

4.1.6. Benefits for road users

The scope of this project ensures that road users will directly benefit from better announcements on traffic restrictions/hazards just ahead in their driving direction. This service is expected to be more timely (reaction time for changes in the system not more than a few seconds) and geographically precise, than the existing methods. In the next C-ITS phase, some additional on-trip warnings to drivers (f.i. approaching to mobile plowing/spreading zone) can be provided. The main principle is: the better drivers' awareness on forthcoming driving conditions means better traffic safety. Also, as previously stated, road users will benefit from possibly better road winter service.

4.1.7. Institutional issues or challenges

High-level political EU and national governments' support was provided for the project, giving the necessary legal and financial base. The main institutional challenges might appear, when commercial partners will join the process with corresponding vehicles' equipment and it's penetration to private fleet. Will it be compulsory or somehow stimulated through the adequate business model by the state, giving enough initial coverage of the proposed C-ITS services? Will it be reliable enough, concerning data circulation inside the system in practice? The other thing, which seems to be overcame by the authorities, but still has a strong resistance in part of society is privacy concern of vehicles' data.

4.1.8. Lessons learned

The project's related field operational tests were done before C-ITS deployment in the involved countries. Other associated projects on EU scale were: CVIS, COOPERS, SAFESPOT, COMeSAFETY, DRIVE C2X and FOTSIS.

4.1.9. Future works

As mentioned before, the project's scope covers only the first and the simplest C-ITS services. It is planned as an "*ice-breaker*" for other related applications for phase 1 and beyond (*illustration 9*). The more complicated algorithms, but also the most valuable outcomes in the future, are expected from V2V communications, towards wider application of automated assistance and autonomous driving in the long-term perspective (*illustration 10*). Here signaling/detecting vehicles will directly warn and influence the driving of approaching ones, without use of the central system, having reaction time of only milliseconds. The European Commission began to work on harmonized C-ITS legislation at the end of 2014.

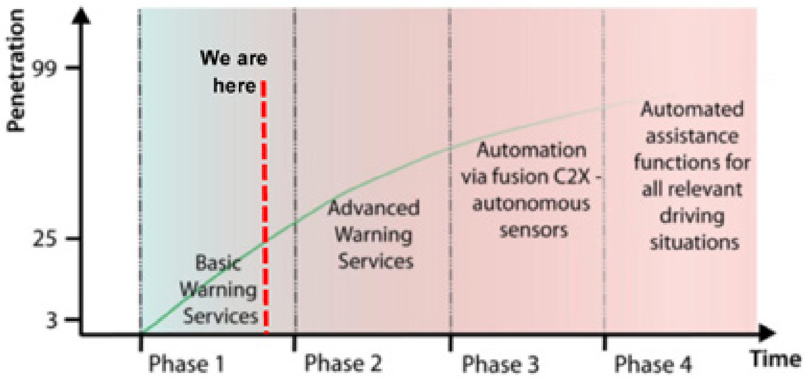
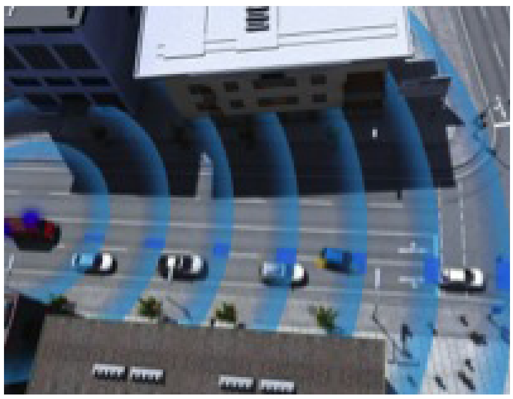


Illustration 9. Conceptual view on C-ITS in long-term perspective

"Day one" services (V2I and V2C based)



Forthcoming services (V2V based)

Illustration 10. Actual and future C-ITS implementations

4.2. MOBI-ROMA

MOBI-ROMA stands for Mobile Observation Methods for Road Maintenance Assessments. The key objectives of the effort were to develop, test, and evaluate improved, affordable, and moderate-cost road condition and performance assessment techniques, which offer new effective tools for monitoring and assessing maintenance needs across Europe.

Status: Finished

Time frame: 01092011-31012013

Owner: ERA-NET ROAD

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Website address /links: ***http://mobiroma.eu***

4.2.1. Description of issue or technology gap

Since the advent of satellite navigation systems that allow vehicle tracking, there has been considerable research and development of monitoring systems that use intelligent cars as sensors. Having several such cars in a fleet results in FCD systems (Fleet Car Data). Most previous studies have concentrated on the use of FCD for the analysis of the traffic state and to develop better traffic information and telematics services.

In MOBI-ROMA, the emphasis of the study is on road surface condition monitoring using data coming from vehicle’s internal sensors through the CAN-bus, or simple devices mounted on the vehicle. Similar techniques with suitable sensors can be used also for assessing strength of road bed or need for winter maintenance. The key target user sector of MOBI-ROMA is road maintenance.

4.2.2. Solution –Satisfaction of the need

The floating car data is retrieved from the CAN-bus outlet or by a purpose-built hardware which is designed to imitate standard sensors equipped in modern vehicles. Floating car data together with data from fixed measuring field stations generate geographically positioned information regarding the roads surface characteristics.

In order to demonstrate the applicability of FCD in road maintenance, a Graphical User Interface (GUI) has been developed to be used as a maintenance tool. The aim with the tool is that the maintenance personnel will be able to have updated knowledge of the road status, to identify needs for maintenance, to perform the proper action that is needed, and geographically map the distribution of the maintenance needs. The tool can be used further to obtain input for cost and time calculation and planning.

4.2.3. Data quality

FCD-data ensure quality by measuring the same stretch of road several times every day. This means that false measurements have minimum effect on the end result. In addition, each measurement method ensures data quality by its own.

4.2.4. Managing data

Data is uploaded automatically using GSM to the Mobi-Roma server and stored in a database. All data collected outside of the project is owned by a specific entity. Data collected during the project is delivered to ERA-NET ROAD on USB-sticks.

4.2.5. Benefits for infrastructure manager / road operators

Better overview of maintenance needs for both managers and operators. The information can be used by managers and operators during maintenance planning.

4.2.6. Benefits for road users

Roads with poor quality are detected at an early stage. This assists road operator’s decision during maintenance operations hence resulting in a higher quality road network. Cars and busses are less stressed hence their services are improved.

4.2.7. Institutional issues or challenges

There several key issues that an implementing agency will need to address. As an example, truck manufacturers have reached consensus on a remote-FMS standard, but there is need for a similar arrangement for passenger cars. Different laws in different countries will also be a challenge.

4.2.8. Lessons learned

- MOBI-ROMA has a complementary character and will not substitute laser measurements. The maintenance tool needs further development, should be simple to use and tailored exactly to the user needs.

- To develop FCD systems, the remaining accessibility problems to CAN-bus data must be solved. This may require a concerted European-wide action such as the implementation of the eCall system.
- MOBI-ROMA service could be used for national or trans-national road maintenance and road transport needs, but the needs differ in various parts of Europe depending on local road climate conditions.
- Large fleet of vehicles would be necessary for the coverage of major roads in Europe. It should be decided what would be the best body to organize and run a European-wide mobile monitoring system.
- Standards for data should be developed and agreed on the European (or international) level so that it is possible to mix data from different type of vehicles and mobile measuring equipment.
- Low cost of communication between vehicles and road side equipment as well as data analysis centers is required.
- FCD fleets can be run with reasonable costs if relying on existing road transport systems, making the mobile monitoring system beneficial for road maintenance.
- There is even greater potential in development of road user warnings based on mobile monitoring data. Just a small reduction of accidents (1%) due to improved road condition data can lead to substantial benefits (100 fold) in both national and European scale.

4.2.9. Future works

To implement, run and exploit mobile monitoring networks still requires plenty of planning and standardization work. In national scale the Road administrations are the natural body to organize monitoring networks to complement the existing systems. However, MOBI-ROMA pilot extended to several EU countries and the results were shown on the web interface. This kind of information would be valuable for trans-national traffic chains. But what would be the best body to organize and run a European-wide monitoring system?

4.3. MOBILE µTEC ROAD SURFACE STATE SENSOR AS VERIFICATION FOR A WINTER MAINTENANCE

Status: Finished, Follow up project in preparation

Time frame: January 2012 - August 2013

Owner: ASFiNAG (Austrian motorway operator), Austria

Participants: Vienna University of Technology

Contact information: Peter NUTZ (peter.nutz@wien.gv.at), Heimo MAIER-FARKAS (heimo.maier-farkas@asfinag.at), T. HAAVASOJA (name.surname@teconer.fi)

Website address /links: *www.asfinag.at, www.tuwien.ac.at/istu, http://keliapu.net/map/*

4.3.1. Description of issue or technology gap

In a previous research project for the optimization of pre-wetted salting, a holistic model allowing the comprehension of winter maintenance strategies on road friction was developed at the Vienna University of Technology. With this model, all relevant factors like precipitation, traffic, treatment rate, road surface texture and friction are accounted for. Basically the applied amount of salt is reduced due to spreading losses and traffic. As a result of hoarfrost, precipitation, drying processes, and road run-off, the resulting water film is mixed with the residual salt and forms a brine on the road surface with decreasing concentration over time and traffic.

Apart from communication and practical implementation issues one of the main drawbacks of such complex holistic models for highly stochastic processes are an accurate determination of the relevant input variables and an on-going calibration based on real-time measurements. For an optimization of winter maintenance processes, the Austrian highway company ASFiNAG decided to assess the potentials for an implementation of the developed model in the research project "*Winterfit*".

Currently the necessary model input parameters are mainly available based on periodic measurements (e.g. texture, skid resistance) or real-time measurements (e.g. precipitation, air temperature, surface temperature, traffic volume) on the highway network in Austria.

The final decision for the actual application at specific road sections remains with the winter maintenance personnel due to their local knowledge and actual perception of the real situation.

Uncertainties in an accurate assessment of road conditions and a selection of appropriate treatment strategies as well as optimal application rates will therefore lead in most cases to higher application rates than necessary. In order to dispel such uncertainties a regular training program with clear and easy to handle instructions is a must. In order to improve the current standard of winter maintenance systems as well as a possible implementation of the developed winter maintenance model, a validation of both RWIS – Sensor {RWIS – Road weather information system} data as well as weather forecasting systems was conducted in the research project "*Winterfit*".

Due to the enormous amount of data on the entire road network the efforts in the project "*Winterfit*" were concentrated on two highway sections with a high number of available sensors and a challenging meteorological terrain. The periodic measurements of road surface texture and skid resistance have been verified with the Griptester Mark II, laser scanning, sand patch method, and a new optical device. The accuracy of RWIS – sensors for continuous measurement of road surface temperature, film thickness and residual salt have been verified with reference equipment as well.

4.3.2. Solution –Satisfaction of the need

RWIS stations alongside the road already deliver information about a specific point on the road. To close the gap between the stations, or to build a new road condition information network, mobile sensors can be used.

The sensor in question was mounted to a car as seen in *illustration 11*. The sensor data is delivered to a smartphone in the cabin using Bluetooth. Therefore the only cable necessary is the power supply cable. The sensor can also be mounted on a free spot in a winter maintenance truck bearing in mind you have to avoid hot spots (engine, exhaust pipe) or the heat would influence the measured temperatures.

With the sensor mounted on the winter maintenance vehicle, two interesting applications are feasible. First of all the measured information about road temperature, surface condition, and other parameters for a road section, or sections, can be sent to the road operator in charge. A second application is the prediction of treatments and salting rates using the road data combined with weather forecast data. An adaptive automated spreading rate is only available if spreaders can be controlled using open data protocols.

Illustration 11. - Teconer RCM411 in Detail

In the road operators control room the state of the road condition can be seen in real time as shown in *illustration 12* below. Using this information the available winter maintenance vehicles can be sent to the critical spots marked in red, orange, or pink.

4.3.3. Data quality

To verify the information gathered from the mobile sensors, RWIS stations have been used. The stations, on the other hand, have been calibrated using manual measurements and test methods. If there are more RWIS stations on the route of a vehicle equipped with the mobile sensor it is also possible to compensate the breakdown of one RWIS station or even to find malfunctions or incorrect measurements. Mobile sensors work without RWIS stations but the reliability of an information network of mobile sensors is way better with the fixed stations.

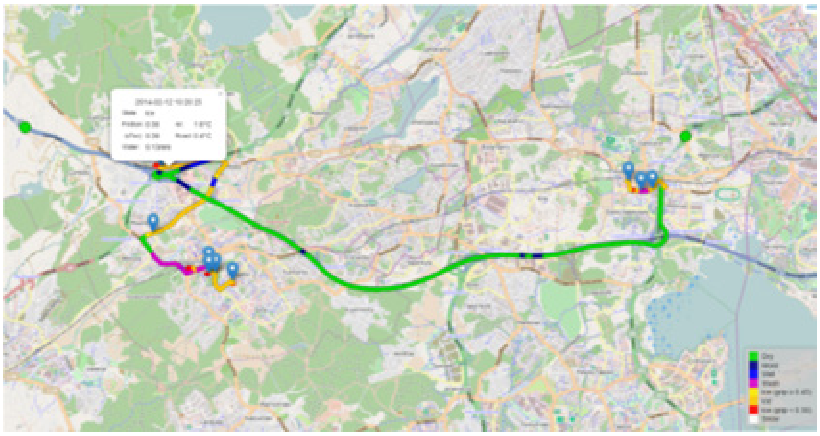

Illustration 12. - Website of Teconer developer

On the data quality it turns out the road and air temperature are quite accurate (detailed statitics available) while the road condition status still have some issues.

4.3.4. Managing data

All data (road condition, weather forecast, etc.) was stored in a database using 50m stretches of road as basic unit in 10 minutes interval. As imaginable the amount of data grew very fast making clever database layout important for the project. Owner of the data is the ASFiNAG as project funding company. The weather data was delivered by the meteorological service to a server where it was processed and written into the database.

With all the data in one database the analysis were made using MATLAB {MATLAB – Mathematical software for data processing} with direct access to the database. Thus, also allows to check data quality and benchmark winter maintenance strategies and plot the data as shown in *illustration 13*.

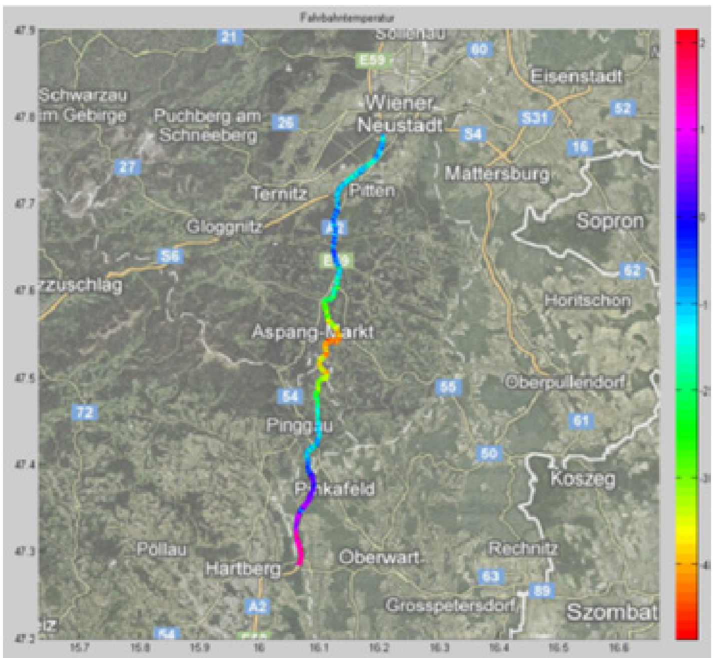

Illustration 13. –
Data analysed with MATLAB

4.3.5. Benefits for infrastructure manager / road operators

Road operators often have a lot of company cars and/or trucks out on the motorways for maintenance work or transport reasons. To generate information about winter maintenance concerning temperature and state of the road surface, RWIS data gathered from one or several points on the road is commonly used, when available. Winter maintenance drivers controlling the state of the road are usually on their own, which might lead to a lack of information and documentation.

Using the presented technology it is possible to gather data about road surface condition of long stretches of the road network. Therefore the road operator is able to set actions very precisely, leading to better efficiency. Unnecessary treatments of the whole network can be avoided if it becomes clear that only several spots are in critical status. On the other hand, necessary actions are identified if any car equipped with the sensor passes the road section.

4.3.6. Benefits for road users

The benefit for road users, apart from the fact that critical road conditions can be treated more efficiently and faster, would lie in the better information to potential commuters before driving. Since it is law in Austria to use winter tires if the road conditions are snowy or icy, drivers with summer tires only can look up the road conditions before leaving and change to other modes of transport. In the current project, however, the information was not brought to the public.

4.3.7. Institutional issues or challenges

As only company cars were equipped there were no legal issues or agreements between user and operator. As a pilot project with only one car the costs were very low. Fitting mobile sensors to a large fleet obviously needs more funds but with strategically selected vehicles it is possible to get a sufficient amount of data without the costs of equipping the whole fleet.

4.3.8. Lessons learned

When combining data from several sources, with different background, and fundamentals, e.g., disparate data, it is a challenge to define the link between the different data. With the link found, it’s even harder to project the input on the same basic principles. The issue of combining various data in one database must be present from the very start of the project.

A good user interface is critical for acceptance of any software by the winter maintenance managers or drivers. There is no use in displaying all kind of parameters on a map, since there is not enough time to check all of them. Also the risk of misinterpretation rises with too much information provided in a bad way. The software has to able to condensate all available information into a clear and easy to read user interface.

4.3 9. Future works

The resulting conclusions regarding necessary requirements and accuracy of weather forecasting, sensor selection, mobile sensors and model calibration can be summarized as follows:

- State of the art now-casting of both air and pavement surface temperature are already feasible for the entire highway network in Austria
- The deviations from actual conditions can be reduced to a satisfactory level if the predictions are calibrated based on temperature profiles and mobile sensor measurements
- Model based automated recommendations for application rates seem feasible on the highway network if the winter maintenance vehicles are equipped with optical sensors for pavement temperature and film thickness
- The remaining uncertainties regarding accurate input parameters for the model can be dispelled either through rigorous training or experienced drivers.

4.4. ROSTMO

The project objective is to develop a system for the registration / verification of road state that with high precision can monitor the condition of the road network in almost real-time. The system of registration / verification of road state should include data from various sources and could be incorporated into a decision support system where forecasting will be an important element.

Status: Ongoing

Time frame: 2014 - 2016

Owner: Iceland, Denmark, Sweden, and Norway

Participants: Iceland, Denmark, Sweden, and Norway

Contact information: torgeir.vaa@vegvesen.no

Website address /links: ***www.nordfou.org***

4.4.1. Description of issue or technology gap

There is a growing consensus in countries experiencing winter road conditions that Intelligent Transportation Systems (ITS) technologies such as Road Weather Information Systems (RWIS), automatic vehicle location (AVL), other vehicle-based monitoring systems and connected vehicles hold enormous potential for making winter operations and driving on winter roads more efficient, cost effective and safer. Real time information made available by these ITS technologies enables winter maintenance agencies to deliver needed treatments at the right location and right time effectively and correctly and to warn the driving public appropriately of hazardous weather conditions.

ITS is a wide-ranging topic and there are several examples of areas where ITS is being used to support winter maintenance operations. Focused internationally, inter alia, has been directed towards the development of decision support systems where weather data are important input. Another example are systems for recording driving conditions where the measurement of friction and wireless transmission of measurement data clearly can carry the tag ITS. *Illustration 14* shows state of the art non-intrusive technology to ascertain the surface condition of the pavement.

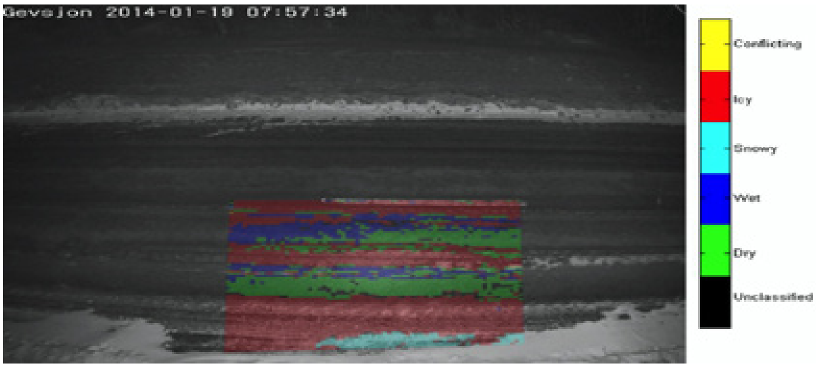

Illustration 14 - Results from the road condition imaging system based on NIR (near infra red) technology[1].

Another area that may be mentioned is systems for automatic data collection that have been in use for many years. Automatic data collection is also an example of the fact that the system itself is not "*intelligent*" until the data is used for active management of winter operations and included in a decision support system.

Real-time information of driving conditions and prognosis for road state development on the road network is an important part of a Winter Maintenance Decision Support System (WMDSS). WMDSS enable contractors and road owners to take action in the right place at the right time with the right method and with proper effort.

Data about the current state of the road can come both from weather stations and from mobile measurements using probe vehicles. This data can also come from cars that act as sensor systems detecting slippery road conditions.

Real-time road state data is an example of ITS applications that can work several ways. Included in the information systems available for the drivers, such systems will have a major traffic safety potential. This kind of two-way communication falls under the concept of cooperative systems which is one of the growth areas for ITS applications.

Illustration 15 - Road Weather Analysis Based on Web Camera Images. Actual condition categorized as partly snow covered.
Source: Vegvær[2]
(user access required)

[1] Jonsson, Patrik, Vaa, Torgeir, Dobslaw, Felix, Thörnberg, Benny: Road Condition Imaging - Model Development. Transportation Research Board Annual Meeting 2015 Paper #15-0885

[2] *https://www.vegvesen.no/vegvar/kart.html*

A common infrastructure that serves multiple uses will help to strengthen the distribution and implementation of ITS measures, which also is an international trend. Research topics within ITS and winter related topics should have a broad approach to extract synergies.

4.4.2. Solution –Satisfaction of the need

One of the main activities in the ROSTMOS project is to conduct tests of different type of technologies; both embedded sensors in the roadway, fixed mounted nonintrusive sensors and vehicle mounted sensors for mobile monitoring of the road surface conditions.

The project will demonstrate how road state data can be collected and linked with other information such as weather conditions and operational measures in the form of snow clearing and gritting. It will also be shown how road state data can be used to improve the forecasting of the development in the driving conditions. How far the project can reach with regards to the forecasting part will depend on synergies with other project initiatives.

4.4.3. Data quality

Data quality is a main issue in the ROSTMOS project. Quality control of data will mainly be based on reference systems. The reference systems will be customized to the technology being tested.

4.4.4. Managing data

Elaboration of how data shall be managed is one of the working tasks in the project. Key words are data collection, quality check, processing, storage and distribution to service providers. DATEX2 will be used for data exchange. DATEX II[3] is a European standard that has been developed to provide a standardized way of communicating and exchanging traffic information between traffic centers, service providers, traffic operators and media partners.

4.4.5. Benefits for infrastructure manager / road operators

Through the ROSTMOS consortium, the project has secured first-hand knowledge of what is happening internationally in this area and it is a goal for of the project to ensure the distribution of information both to the governmental side, to the performing side (contractors), to the industry, and to other business sectors.

The idea is that the solutions being worked out in the project will support both strategic and operational decisions made by the road owner, contractors and traffic information centers. In addition to contributing to making winter operations more effective and improve traffic information systems, the project will also demonstrate how ITS can be used in quality control and documentation.

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[3] *http://www.vegvesen.no/en/Traffic/On+the+road/Datex2*

Partial deliveries will be:

- State -of -the -art in terms of methods of recording road state
- Testing and evaluation of various detection methods, what exists internationally in this area?
- Examples of systems for decision support - status in the Nordic countries and internationally
- Recommendations and proposed architecture for decision support system based on different sources for road state information
- Information flow - feasibility study and proposed information solutions; it will, in principle, be an implementation guide. Will be tested through pilot projects to the extent of the resources within the budget for the project

Illustration 16 - Marwis optical sensor from Lufft to be tested in the ROSTMOS project; will be compared with Teconer RCM411 and MetRoad Mobile, from MetSense.
(Photo: Torgeir Vaa)

4.4.6. Benefits for road users

The project targets improved traffic safety during winter conditions as a main outcome and all road users will benefit from the results from the project.

4.4.7. Institutional issues or challenges

One major institutional challenge will be to build an organization that maintains the infrastructure, manages, and interprets the huge amounts of data from various sources.

4.4.8 Lessons learned

Lessons learned so far is that the new technologies studied in the ROSTMOS project provide a significant contribution to monitor driving conditions on the road network and give important input to improve the prognosis tool for development in the road state.

4.4.9. Future works

Future work look into integration of real time road state data into the models in WMDSS and traffic information systems.

4.5. BLUETOOTH SENSORS USE CASE

Status: The project is deployed along 105 km of A63 motorway in France. The Concessionaire Company is ATLANDES and the Operator is EGIS Exploitation Aquitaine

Time frame: The project was launched at the end of 2012 and was scheduled to be completed by the end of 2014

Owner: Egis Exploitation Aquitaine

Participants: Egis Road Operation (Egis Road operation (Head Office of Egis Exploitation Aquitaine), Egis Exploitation Aquitaine and the company ARS Traffic & Transport Technology

Contact information: Didier DIEM Egis Road Operation France, +33 1 39 41 43 67

Website address /links: *info@ars.nl, www.ars.nl, www.atlandes.fr*

4.5.1. Description of issue or technology gap

A63 is a new motorway in the South West of France and carries about l0000 heavy goods vehicles each day from and to Spain and Portugal, roughly one-third of the daily traffic load. Heavy goods traffic has increased by 56% between 1997 and 2005. It is predicted that this will continue for at least the next ten years. There is a rule that heavy trucks are forbidden to travel a part of the weekend, but not all comply with this.

The current public/private partnership (PPP) contract obligations of A63 between Salles (Gironde) and Saint-Geours-de Maremne (Landes) ask Egis Exploitation Aquitaine to address the data services identified below:

- Traffic data reports are required to fulfill the contractual requirements on KPI reporting to the authori-ties.
- Incident detection at the stretches where traffic monitoring is present
- Travel times need to be delivered to road users.

A Traffic Control Room monitors the motorway 24 hours/day, seven days a week, 365 days/year. Inductions loops have been implemented and they will be used for data delivery. However, this cannot guarantee sufficient quality of travel times. The induction loop data are likely to provide good quality data in terms of traffic flow (traffic intensities), but the derived travel time data will be of lesser quality, in particular during time of congestion when the quality requirements are highest.

4.5.2. Solution –Satisfaction of the need

Working principle:
The Concessionaire Company was reluctant to install new road monitoring equipment due to the impact this may have on investment costs and operational costs.

Alternative solutions
In order to fulfill the requirements, three alternatives have been analyzed:

1. Use already available data
2. Procure equipment and create the required data
3. Acquire a data service that provides the required data

It was decided to implement the option 3 as it is both realistic and matches the client requirements. It was analyzed whether the service could be based on pre-existing data only.

The implemented solution is a hybrid data monitoring service, using available data sources, as well as limited new data sources.

Description
The core of the proposed solution is the ARS T&TT (intelligent transport system consultancy) Traffic Data Warehouse (TDW). At the TDW all available and new traffic data is collected and processed into the information required by Egis. From the TDW a reporting service can be started from a web interface that will provide the reports of the traffic data in the format required.

The TDW has generic middleware to which a multitude of data sources can be connected. For the purpose of this implementation, an interface for the loop detectors shall be enabled, as well as an interface for Bluetraffic sensors (see *illustration 17* below) The Bluetraffic sensors will allow the monitoring of high quality travel times on the A63 and can be implemented by ARS T&TT as part of a service agreement. The traffic intensity data can be supplemented by the data from the loop systems, which have exactly the reverse characteristic in the sense that they provide excellent traffic intensity data, but travel time data of limited quality.

At the TDW, the data is recorded and processed and distributed to channels, both professional ones and end-user ones. The TDW and the sensors are monitored 24 hrs a day, 365 a year from the dual redundant ARS T&TT traffic data center.

For an Operator, this model has the additional advantage that the information provided is unique and can be used for marketing and branding purposes for regular users.

Illustration 17. – Bluetraffic sensor
(photo Egis)

Bluetraffic sensors implementation is based on the monitoring of unique identifiers in Bluetooth equipped vehicles. The Bluetraffic technology is cost efficient in implementation and operation and provides excellent travel time data and reasonable quality intensity data. Bluetooth sensors can be installed on the road side in small enclosures and require limited power. As a result Bluetraffic can be powered from solar panels, or from light poles. The installation of a Bluetraffic sensor requires not more time than 15 - 30 minutes. The sensors can be remotely read and updated.

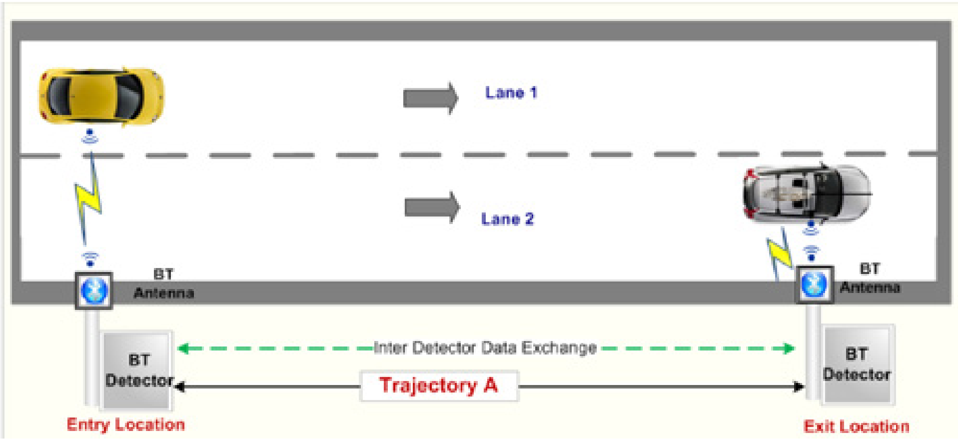

Illustration 18. (Egis)

For Bluetooth sensors implementation, the proposed method is to mount small directional Bluetooth receivers and antennas on overpasses above the middle lane in each direction of the A63 (illustration 18). The Bluetraffic unit will connect to a road side unit that ensures solar powering. The 100•120 Wp solar panels will ensure that the Bluetraffic systems will be able to exchange data on a continuous basis. The Bluetraffic unit will:

- exchange its data with the Traffic Data Warehouse (TDW)
- server using mobile Internet.

The data from the Bluetraffic sensors will be fused in the TDW with the traffic flow data from the loop data and will be made available to the users through the TDW webserver.

4.5.3. Data quality

The performance of Bluetraffic on the A63 in the proposed configuration will yield a performance of 30-50% detection rate. This rate will ensure travel time accuracy above 90%. In particular during the peak traffic times, Bluetraffic will ensure a high quality representation of travel times.

4.5.4. Managing data

The administrator of the system may configure the alerts in terms of deviation levels and the corresponding alerts.

For Bluetooth option, speed, and Traveltime (delaytime) Alerts will be visible if user has configured that particular alert type and data is meeting the alert criteria.

For Loop option, Alert can be configured for Intensity and speed value. Alert will be visible on viewer screen if intensity data for selected date and time is meeting the alert criteria. Alerts may be configured as

- visual operator alerts,
- operator audio alerts (various signals and levels),
- email messages
- SMS messages.

The system can be configured to log all alerts for audit trail purposes.

4.5.5. Benefits for infrastructure manager / road operators

On the basis of the traffic data of regular traffic that is collected, a history will be built by the TDW that indicates what regular travel times are on the various stretches and what regular traffic intensities are. This will be a time series which will be based on patterns within a 7day week. On the on-line visualized schematics of the A63 that are available to the operator the expected travel times, speeds and traffic intensities will be shown. Major deviations from the presented values will result in alerts.

Report Generation: reports can be exported using Export to PDF, Excel, and CSV options. Upon clicking the report icon from the control panel, a report screen will open and it would be possible to choose the type of report (Bluetooth; loops; both; a section; a loop; etc.). See *illustration 19* below.

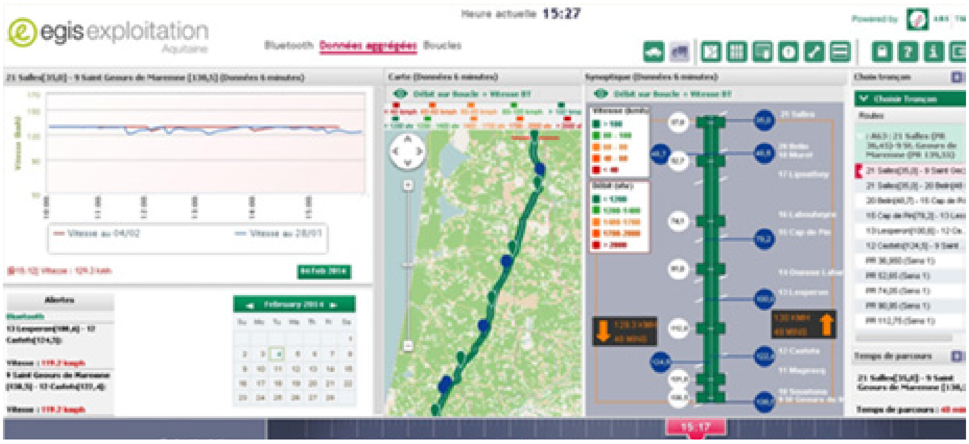

Illustration 19, Reporting capability (Egis)

4.5.6. Benefits for road users

Two mains benefits were obtained from the system:

- An accurate travel time,
- Incident detection improvement

4.5.7. Institutional issues or challenges

Deployers of this technology will likely need to address: funding and legal issues; how capital intensive is this project? Is it too expensive? Technology; working relationships between partners; who is the data source (i.e., private fleet, public fleet)? Do we need a partnership agreement? Any entities supporting/opposing the project?

4.5.8. Lessons learned

Four main lessons

- Blue tooth capture rate is enough to derive travel time in standard situations
- The system struggles when traffic numbers are not high enough, typically under a couple of 100s per hour
- The system is not so responsive in heavily congested situations
- Detecting congestion in real time requires high density of blue tooth sensors

4.5.9. Future work

More and more cars are equipped with this technology. Future works are to find the good equation between equipment installed along a motorway and the level and quality of the collected information.

Results have to be compared to normal technology, i.e., inductive traffic loops, ANPR system. Bluethooth technology will evolve in the next years and we have to follow and see the impact of the evolutions.

4.5.10. Conclusion:

We can summarize in four points the main advantages of this technology

- Blue tooth system is well suited for travel time calculation on interurban motorways
- It cannot make up for a robust incident detection system (CCTV Closed-circuit television or oth-erwise) unless a very high number of sensors are installed, which is uneconomical
- Bluetooth outprices ANPR for long distance travel time measure
- Compared to FCD, the key advantage is to be independent from third party data (social net-work, mobile operators, etc.)

4.6. USING VEHICLE SENSORS TO UNDERSTAND DRIVER BEHAVIOR

The purpose of this project was to use data analytics to extract driving behavior information from CAN bus data. Here, a business unit of Nokia, offers products and cloud services that service the contextual needs of mobile users. Here's location content and analytics provide the foundation on which to codify driving behaviors and allow for on-board driver assist systems as well as fleet level broadcasting services. With advanced analytics of the on-board sensors, the driver can have a better experience, improved safety and context for their journey ahead.

Status: Ongoing

Time frame: The original data received by the Here organization was from 2013

Owner: Jane Macfarlane, Here Research, United States

Participants: Original data came from Beijer Automotive, The Netherlands

Contact information: Jane Macfarlane, jane.macfarlane@here.com

Website address /links: N/A

4.6.1. Description of issue or technology gap

It was in the mid-nineties that the first consumer navigation device emerged on the market. Embedding a radio in the vehicle to connect to the cellular network followed this, and the world witnessed the birth of telematics, the first ones being deployed on the analog cellular network. This gave us the "*where*" of the vehicles with a limited understanding of the state of the vehicle. Since then, with the growth of the mobile phone market, we now have a digital infrastructure that can be leveraged to aggregate the rich sensor information that has historically been locked within the vehicle.

Today, we sit on the cusp of the confluence of the enabling components for the birth of what we would like to call "*The Behavioral Map*". Specifically these enabling components are:

- Ubiquitous high bandwidth data networks, and
- Hardware and software innovations that have significantly improved sensors both in their computa-tional capabilities as well as their power requirements.

This combination of bandwidth and sensors will allow road managers to understand how car users dynamically experience the road network. That is the "*How roads are driven*" as opposed to "*How they are designed to be driven*". Whereas Advanced Driver Assistance System (ADAS) currently considers the geometry of the roads, this approach allows us to understand the experience of the road.

4.6.2. Solution –Satisfaction of the need

The Smart-in-Car project in the Netherlands is informing HERE research project. The Smart-in-Car project has demonstrated the opportunities to improve traffic flow and increase traffic safety. It helps the region of Eindhoven (Netherlands) to monitor and report dangerous road conditions in real time and warn drivers in the vicinity to avoid accidents. The first data set was collected from 81 taxis in the city of Eindhoven. Just 8 weeks of data generated 17 million GPS locations and over 37 million CAN (Controller Area Network) bus sensor values. Additional data sets that were acquired had additional vehicles totaling to 120 vehicles. It is a complex data environment consisting of different vehicle types. There are common sensors across vehicles – eg. speed and rpm, and other sensors that are specific to the vehicle model. The sensors are not necessarily correlated in time with Global Positioning System (GPS) locations and as a consequence location information is derived from adjacent GPS information. Examples of available sensor data: Accessory, Brake, Driver Door, Engine Run, First Gear, Front Fog Light, Fuel Consumption, Hazard Lights, High Beam, Ignition, Low Beam, Passenger Door, Reverse Gear, RPM, Speed, Steering Position, Throttle, Wiper Fast, Wiper Once, Wiper Slow and many others.

4.6.3. Data quality and Managing data

The data sets that HERE research acquired were raw data sets supplied by Beijer Electronics who possesses technologies that can read the CAN bus signals from over 90% of existing cars. It is archived data that is collected over periods of time. As a consequence, the data quality issues must be addressed by the data analytics. There were data anomalies surfaced in the analytics process – examples include: duplicate entries for the same time stamp, invalid GPS time stamps, invalid GPS coordinates, time stamp anomalies and position anomalies. These types of quality issues are to be expected when creating new systems for measuring sensors that were not initially designed for a data collection process.

4.6.4. Benefits for infrastructure manager / road operators

Understanding behavior of drivers on the road network will provide increased understanding of hazardous road geometries as well as hazardous road conditions. With this kind of information, road operators can provide warning systems that will notify drivers to change their behavior to accommodate conditions ahead.

4.6.5. Benefits for road users

The focus of this research is to understand behavior on the road network and learn successful approaches for navigating the network. This information will not only inform road network designers, it can also provide advice to drivers as they approach hazardous situations. This can assist the traditional driver in a variety of situations – for example when inclement weather creates road conditions that require a change in behavior on the road to accommodate slippery road surfaces or conditions in which visibility is reduced. In this manner, these notifications provide information about changes ahead that the driver might not be expecting. In addition to a typical driver that is used to the specific road network ahead, this type of information can be extremely useful for other categories drivers such as: teenage drivers who are learning to drive and drivers who are unfamiliar with the road network ahead.

4.6.6. Institutional issues or challenges

The ecosystem for generating this data is forming currently. It is important that these types of data sets are available such that research efforts like this can begin to develop mechanisms for mining this type of data. Sensor data from vehicles has a potential to create very large data sets that will require Big Data analytics for understanding the value in the data. This type of research can provide insights into what data to collect, where in the ecosystem to process the data, what kinds of communications systems will be needed to enable the data collection and how to mine the value from the data.

4.6.7. Lessons learned

By just looking at windshield wipers on WiperFast state and speed changes, heavy rain can be tracked as it moves through the City of Eindhoven. This is shown as the blue points in the *Illustration 20* below. It represents a snap shot in time during the rain storm. Safety warnings can be generated and sent back to approaching vehicles to slow for the rain up ahead.

With the additional sensors in the vehicle we can learn more about how drivers might modify their behavior to accommodate a rain environment. *Illustration 21* shows the speeds at which drivers apply their brakes during a rain storm.

Illustration 20. - Windshield Wiper Information / Illustration 21. - Braking Speeds During a Rain Storm
(graphics courtesy of Jane McFarlane, Here Research)

A final example shows how drivers brake when entering a curve. GPS and vehicle braking information are combined to determine where drivers actually brake to decelerate when approaching a curve. The focus here is to look for a behavioral understanding of how roads are actually driven as opposed to how they are designed or regulated by law. *Illustration 23* shows the GPS data for a sharp curve. It represents 25 days of data, 46 vehicles and 1,529 probe reports. We take one direction of travel - north to south - and separate the vehicles by the speed at which they enter the bounding box.

Illustration 22. -
Probe Data for Sharp Curve

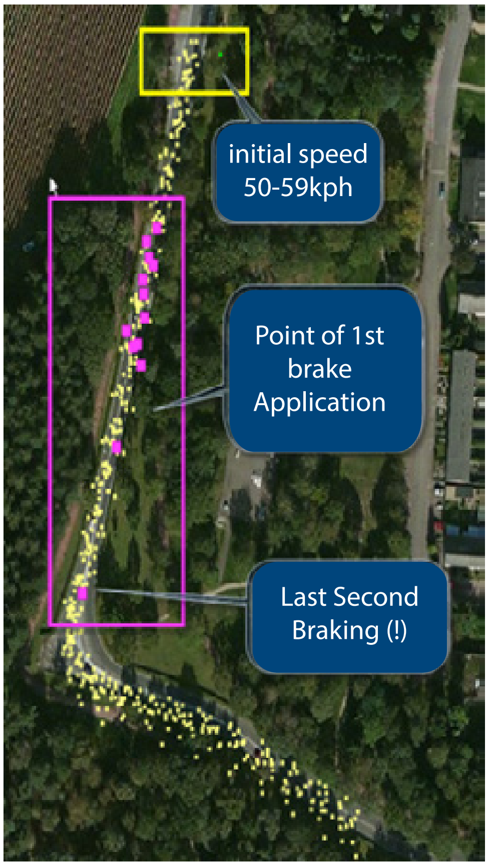

Illustration 23. -
Vehicle Entering at 50-60 km/h

For each vehicle bin and for each trajectory, the point where brakes are first applied. *Illustration 23* shows an example of vehicles entering into the area at 50 to 60 km/h. The centroid of those braking points are determined - *illustration 24* shows the centroids as cyan points as a function of entering speed. It clearly indicates that the speed at which you enter this area impacts the location at which you must start applying your brakes. A histogram of the vehicles and their braking speeds are shown in *illustration 25* The static maps tells us much about the road - the road name, the link id, the link lengths, it is a bi-directional one lane road, it has no divider and its speed limits is 50 km/h.

Illustration 24. -
Braking Centroids for Various Entering
Speeds (from top to bottom:
70km/h, 60km/h, 50km/h, and 40km/h)

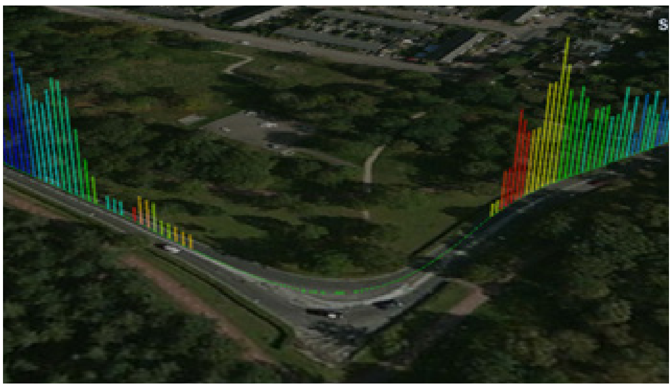

Illustration 25. - Braking Speeds

(graphics courtesy of Jane McFarlane, Here Research)

With our additional information, an understanding of the general behavior of the drivers can be derived and can directly inform drivers in real-time where to start braking and at what speed they need to decelerate to - in this case approximately 30 km/h. In addition, with additional information about the curvature of the road (a part of an ADAS enhanced map) we can determine the lateral acceleration of the vehicle.

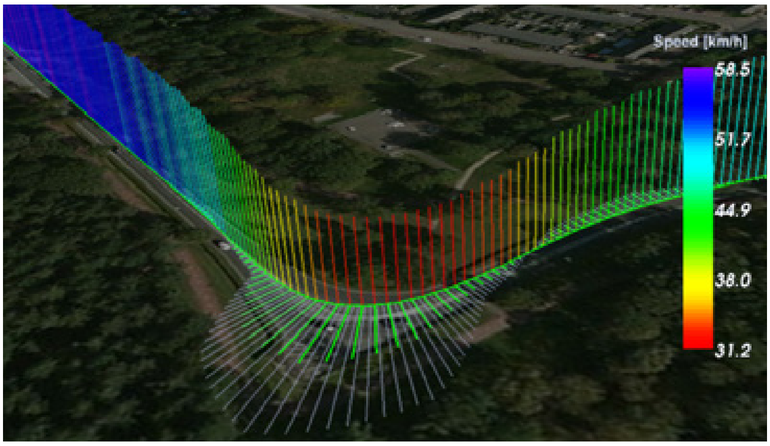

Illustration 26. – Lateral Acceleration
(graphics courtesy of Jane McFarlane, Here Research)

This is indicated in *illustration 26* as the green lines that emanate out of the curve. The white lines indicate the curvature of the road. *Illustration 11* indicates later acceleration for a northbound entry. This same information can be generated for a southbound entry as well and thus can provide direction of travel accommodation for the navigation of the curve. Furthermore, with the windshield wiper information we can learn about accommodation in a rain storm or with headlight information we can learn about accommodation in night versus daytime conditions.

4.6.8. Future works

There is no doubt that the vehicle can be a sophisticated sensor system that can provide valuable information about our road networks. Here, through it Connected Driving business unit, it addressing this challenging problem and will be a key participant in the emerging ecosystem to support this effort.

4.7. 5.9 GHZ DEDICATED SHORT RANGE COMMUNICATION VEHICLE-BASED ROAD AND WEATHER CONDITION APPLICATION

What: 5.9 GHz DSRC Vehicle Based Road and Weather Condition Application

Where: New York State, USA

Status: Project is finished / 100% complete.

Time frame: Winter 2012 – Summer 2015

Owner: Cooperative Transportation Systems Pool Fund Study (Research consortium of several USA States; lead by the State of Virginia)

Participants: Pool Fund Study Members- Transportation Agencies from the States of Virginia, New York, Minnesota, others; Federal Highway Administration; Consultant Team lead "*Synesis Partners LLC.*"

Contact information: Mr. Richard McDonough (Richard.McDonough@dot.ny.gov) 1-518-457-5871; Mr. Gabriel Guevara (Gabriel.guevara@dot.gov) 1-202-366-754

4.7.1. Project Background and Objective

Significant effort has been expended in the United States of America (USA) to identify opportunities to acquire data from vehicles acting as mobile sensor platforms. Government officials, academia, and interested private sector parties, have also been working with automakers and communication technology providers to develop and standardize information exchange between vehicles (V2V) and between vehicles and the transportation infrastructure (V2I), enabling a variety of applications that could improve transportation safety, mobility and environmental performance. This use case highlights a project undertaken by a consortium of state transportation agencies that pooled funds and other resources to demonstrate how vehicle platform data can be collected, processed, and transmitted by a prototype application using 5.9 GHz Dedicated Short Range Communication (DSRC). The expectation is that the additional weather information collected from mobile platforms, in conjunction with the more traditional sources of weather and transportation-related information/data, will enable traffic managers and maintenance personnel to implement operational strategies that optimize the performance of the transportation system by mitigating the effects of adverse weather.
This project endeavored to accomplish the following tasks:

- Task 1. Requirements Development
- Task 2. Concept of Operations
- Task 3. Application Development
- Task 4. Application Installation and Testing

4.7.2. Description of the Issue or Technology Gap

As the Connected Vehicle initiatives continue to mature and higher penetration is achieved, copious amounts of vehicle-based data will be collected. Thus, it is necessary to investigate how the mobile sourced data will be collected, transmitted, and incorporated into applications that result in actionable information to users to further safety, mobility, and environmental goals. The intent of the Connected Vehicle Pooled Fund Study (CV PFS) effort was to develop a deployable 5.9 GHz dedicated short range communication (DSRC) application to advance the state of the knowledge in the aforementioned areas and, specifically, to supplement the mobile data aspect of the Clarus Initiative (renamed the Weather Data Environment (WxDE)- *http://wxde.fhwa.dot.gov/.*)

4.7.3. Solution –Satisfaction of the need

This project resulted in the development of a prototype weather-focused application that collects data from state vehicle fleets and uses a 5.9 GHz dedicated short range communication platform to collect and transmit the data- this is a vehicle to infrastructure solution. The application is capable of 1) obtaining mobile data, including data from the J1939 data bus and various peripheral devices from maintenance vehicles, i.e., external sensors 2) transmitting this data to a compliant 5.9 GHz DSRC roadside equipment (RSE) 3) sending the data from the RSE to a central server and, 4) processing the data and feeding it to the Weather Data Environment hosted by the FHWA, New York State Traffic Operation Center's INFORM System, and other systems for use in determining and/or predicting road and weather conditions. Project Location Information: Long Island Expressway (LIE) / New York State; Volume: 178,000 AADT; Land Use: Urban. This location was selected because of existing communication backhaul; existing roadside infrastructure; and its proximity to New York State DOT maintenance facilities.
Hardware employed

Hardware employed

OBU:	Cohda MK2 (~$4800) and MK4 (~$2900)
RSU:	Savari (~$7800)
Vehicles:	Mack snowplow trucks and Ford F-350 Pick-ups
Road and Weather Sensor:	High Sierra Electronics IceSight (~$5000)
Communication Platform:	Dedicated Short Range Communication (DSRC); fiber Optic Backhaul; Internet

3.7.2.1. System Architecture

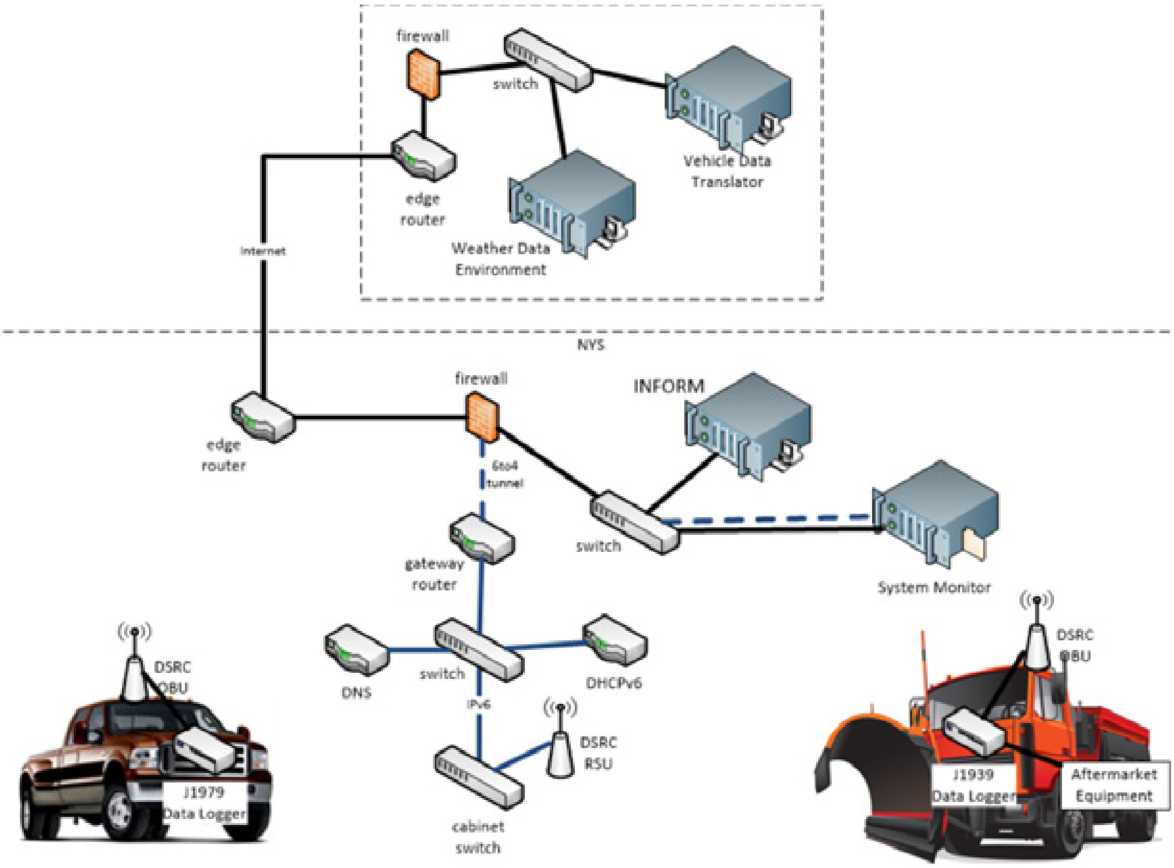

Illustration 27. – System Architecture

4.7.4. Data Quality

Mobile data was collected from a Mack snowplow truck; from a Ford pick-up; and from an Icesight sensor. Can-bus data from the snowplow truck and from the pick-up was limited to legislated (published) parameter and governed by the SAE J1939 and SAE J1979 respectively; data elements from the IceSight sensor is made available as per the manufacturer specifications and, generally, it conforms to the NTCIP 1204 standard. To every extent possible, this project endeavored to encapsulate the probe data in accordance to the basic Safety Message (BSM), following the J2735 communication standard. Quality control/Quality Assurance of the data are performed as part of the quality checking algorithms of the Vehicle Data Translator and of the Weather Data Environment (*http://wxde.fhwa.dot.gov/ .*)

4.7.5. Managing the Data

Since the data are collected using vehicles in the public domain and using government funds, the data belongs to the public agency generating the data; in this case the New York State Department of Transportation (NYSDOT). The data router receives the BSM data from RSUs and immediately shapes and sends the data for the destination systems where the data are used to provide value-added information to transportation officials and to the traveling public (via the WxDE and/or the INFORM system.)

The Weather Data Environment archives the received weather data; this is possible due to a Data Sharing Agreement between the NYSDOT and the Federal Highway Administration, who owns and operates the WxDE. Personally Identifiable Information (PII) is not an issue for this project. All the data being gathered is coming from government fleet vehicles; no PII from the drivers per se is being collected and the information concerning their destinations and patterns is in the public domain.

4.7.5.1. Steps for Data Collection, Transmission, and Manipulation

1. Snowplows and light duty trucks equipped with connected vehicle technology operate on the roadway gathering data.
2. Sensors on the vehicle measure and report data to the vehicle's data bus (typically the CAN-bus); externally mounted sensors are collecting pavement and atmospheric data as well.
3. The vehicle's on board equipment (OBU (onboard unit)-Cohda) obtains weather-related data from the data bus and from the IceSight and other aftermarket sensing devices.
4. OBU formats data into a basic safety message (BSM).
5. OBU temporarily stores BSM for transmittal.
6. Vehicle comes in range of Road Side Equipment (RSU); OBU receives service announcement from RSU-DSRC communication Platform.
7. OBU broadcasts saved BSM to RSU.
8. RSU logs incoming message(s).
9. RSU pushes logs to the data router over the backhaul network.
10. Data router shapes data and sends to other systems, i.e., WxDE, VDT, INFORM.
11. WxDE receives data.
12. INFORM System at New York State Department of Transportation (NYSDOT) receives data.
13. VDT receives data.
14. VDT synthesizes weather data from vehicle data.
15. Users obtain data from WxDE.
16. Users obtain data from INFORM.

4.7.5.2 Data Elements

A J2735 probe vehicle data message consists of a set of snapshots, and each snapshot includes the vehicle location and vehicle status. There are fourteen weather-related data elements in the vehicle status data frame (exterior lights, wiper status (front and rear), sun data, solar radiation, air temperature, air pressure, rain data, precipitation situation, etc.)

The probe vehicle data message captures all of the available weather data elements from J1979 and most of what is available from J1939, except for road surface temperature and plow-blade status. The probe vehicle data message includes solar and rain data that are not directly available from either J1939 or J1979 by default, but may be available from other aftermarket equipment connected to those buses.

Third-party/aftermarket equipment data collection units are needed to fill in the data that is either missing or non-discoverable from the vehicles CAN-bus. In this project the decision was made to use the IceSight 2020S Remote Surface condition Sensor. This sensor collects air temperature and relative humidity (at the sensor), and pavement surface temperature, condition (wet, dry, snow, ice), and grip/friction.

4.7.5. Benefits to the Infrastructure Manager / Road Operators

In the case of the Long Island Expressway, The New York Department of Transportation is the owner and operator of the facility. As stated above, this project endeavored to prototype a V2I system that takes advantage of emerging connected vehicle technologies, such as the DSRC communication platform; reads weather-relevant data from the intrinsic vehicle sensing systems via the CAN-bus; collects data from externally mounted sensors; packages the data into a well-defined probe message, and transmits the data to a number of data systems and environments. The real value of this successful demonstration is the various potential applications that can be enabled by this rich, near real-time data set. While the description of these applications is beyond the scope of this project, one can think of the friction parameters collected by the IceSight sensors being used by winter maintenance agencies to gauge the effectiveness of their actions, i.e., Performance Measures; the ABS (Anti-lock Braking System) of the vehicles as well as the vehicle speeds could be correlated to pavement surface conditions and enable the system manager to enact weather responsive traffic management strategies in an effort to ensure adequate safety and mobility of the traveling public.

4.7.6. Benefits for the Road Users

The near real time data collected by this particular system was meant to be used by systems like the WxDE, and the NYDOT's "INFORM" System. In one way or another, all of these systems provide added value to the data (particularly in terms of quality checking) and can be used to provide actionable, near real-time information to the roadway user. The INFORM system, for example, is considered to be a state-of-the-art Traffic Information System intended to help improve the mobility and safety of Long Island motorists; it utilizes a vast array of strategically located road-embedded sensors and cameras, and other information sources, and after processing all the input data, it provides near real-time travel information to motorists via electronic signs along the road and via other various media. This information helps motorists make educated traveling decisions, thereby helping to reduce traffic congestion; provides for travel time savings; reduces fuel consumption and emissions, and potentially decreases the accident rate along the corridor.

4.7.7. Institutional Issues or Challenges

Entities considering implementation of mobile data platforms such as this one will have to overcome many challenges; some of them are captured here:

Infrastructure cost: in addition to the data collection expenses associated with the mobile platforms and DSRC roadside units, these types of projects are dependent on the communication backhaul necessary to transmit the data from the field to the point where it is going to be processed. In this particular case, the Long Island Expressway provided their extensive fiber-optic network able to support Internet connectivity between the roadside equipment and the destination systems. Should there be a need for frequent data downloads where the density of RSU is not high enough, a hybrid Cellular/DSRC communication platform could be implemented.

Governance: while this project is totally government owned and funded, there are opportunities for partnering with the private sector interested in probe-vehicle data and willing to share costs. Depending on the geographical scale of the project and who the data contributors are, there may be a need to establish data sharing agreements and multi-jurisdictional agreements concerning Operation & Maintenance of the system.

Standards: since the technologies associated with a project of this nature are rapidly evolving, it is imperative that early adopters abide to whatever existing governing system architectures and standards may be in place.

Data Privacy and Intellectual Property Issues: depending on the sources of data (private vehicle fleets) it may be necessary to secure data sharing agreements with each individual contributor. n the US, the Connected Vehicle Program is committed to safeguarding personal identifiable information (PII). Additionally, entities embarking on these types of investments should do a search of existing and imminent patents or intellectual property rights that may have an impact on their deployment plans.

4.7.8. Lessons learned

The need to integrate several disparate systems and make it all work to achieve very specific goals proved to be a challenge. The complexity of projects like this one is generally proportional to the scale of the deployment. The agency needs to ensure that data and information flow securely and reliably regardless of the circumstances, i.e., geographical and jurisdictional boundaries, specific vehicle platform (make, model, year,) etc. Additionally, it is very difficult to get meaningful data from the vehicle CAN-bus without cooperation from the automakers; entering into non-disclosure agreements (NDA's) with them can be a way to facilitate the data "*discovery*" process.

4.7.9. Future works

Much was learned as the result of this project but, admittedly, much remains to be learned. It would, for example, be interesting to expand the scope of this project in terms of area coverage, fleet mix (public, private, vehicle make and models, etc.); test different field equipment (perhaps even perform a cross comparison of the equipment). A larger scale deployment would result in a better appreciation of how well the system architecture performs under higher communication/ data demands; it may help determine the suitability or gaps in the existing communication standards; would help test the adequacy of existing agreements; and more. This project will be completed by the summer of 2015, but it is likely that additional work will follow should additional funding become available.

4.8. NEVADA DEPARTMENT OF TRANSPORTATION'S INTEGRATED MOBILE OBSERVATIONS PROJECT

Objective: The over-arching objective of the project was to demonstrate how weather, road condition, and related vehicle data may be collected, transmitted, processed, and used for decision making as part of the Intelligent Transportation System (ITS) Integrated Mobile Observations (IMO) project of the USDOT.

Status: IMO 1 & 2 complete. Final report drafted. IMO 3 is ongoing. IMO 3 to be completed by 2017 and DSRC is a part of the communication platform.

Time frame: IMO 1 started 2010 (under the umbrella of the former USA IntelliDrive initiative, now called the Connected Vehicle initiative), expected completion 2017.

Owner: Nevada DOT with funding from USDOT-FHWA

Project Participants: Nevada Department of Transportation (NDOT), Federal Highway Administration (FHWA), University of Nevada-Reno (UNR); National Center for Atmospheric Research (NCAR).

Contact information: Denise Inda (dinda@dot.state.nv.us); Richard Nelson, (rnelson@aashto.org), Gabriel Guevara (gabriel.guevara@dot.gov)

Website address /links: IMO Phase I Report *http://ntl.bts.gov/lib/48000/48300/48314/Final_Report_Task_5b_5-31-131.pdf*

4.8.1. Description of issue or technology gap

The Nevada Department of Transportation (NDOT), in collaboration with the University of Nevada, Reno (UNR) and the National Center for Atmospheric Research (NCAR), was selected by the Federal Highway Administration (FHWA) to participate in the demonstration project Integrated Mobile Observations (IMO). At a regional level, the main project objective was to develop a prototype IMO system for Nevada that addressed two of NDOT's critical needs:

1. Improved system-wide performance monitoring and measurement methods and tools. The Nevada IMO (NIMO) project uses on-vehicle instrumentation to dynamically gather near-real-time localized weather, road condition, material usage, and vehicle-related data that will be used to gauge road conditions and better inform safety processes (such as chain controls) by providing this data to supervisors and operators through mediums such as FHWA's Weather Data Environment.
2. Improving Freeway/Highway Maintenance Operations and Equipment Maintenance. Near-real-time weather, vehicle, and road condition data that will be used by NDOT personnel to improve highway maintenance operations both in terms of increased level of service and cost savings through applications such as the Enhanced Maintenance and Decision Support System (MDSS) and a Maintenance Management System (MMS).

4.8.2. Solution –Satisfaction of the need

In order to meet the project needs, the NDOT / UNR team, devised a data collection and transmission system that took advantage of the existing DOT Vehicle Fleet and of the Radio Communication system. The overall architecture of the system is represented in fig. 28 below. At a high-level, the system components were:

1. NDOT-owned vehicles (snowplows and Light-duty pick-ups) equipped with mobile data collection and processing unit (MDC); CAN-bus reader/interface; weather sensors, AVL/GPS unit, etc. for data gathering and telemetry.
2. Communications backhaul: Operational/existing 800 MHz EDACS (Enhanced Digital Access Communications System) radio system for data transmission.

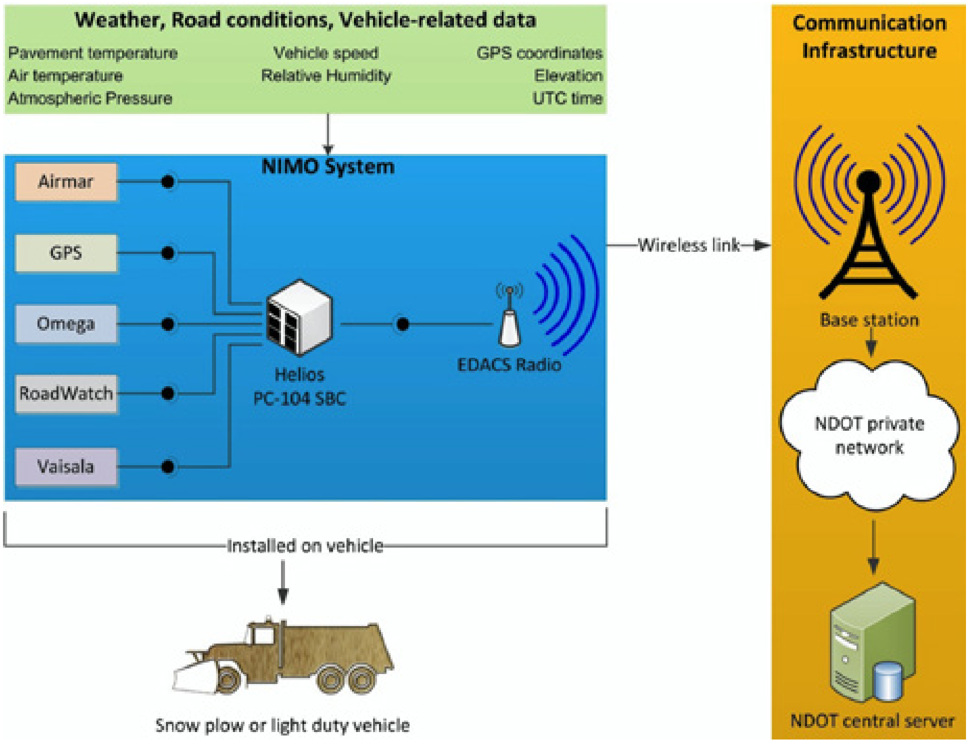

Illustration 28. – System Architecture

4.8.3. Data Collection and Quality

The team selected a rugged, PC-104 single board computer (SBC) to serve as the "*brain*" of the system and developed custom client software that runs on the PC-104 and collects the data from the instruments, logs the data, processes and aggregates it, and then transmits it using the on-board EDACS radio through the EDACS radio network to a central server (*illustration 1*). From the central server, the data was sent to the National Center for Atmospheric Research (NCAR) and to the Weather Data Environment (WxDE) (*http://wxde.fhwa.dot.gov/*). The central server, in this case, was hosted at the University of Nevada-Reno (UNR) and there, checks were only performed at the data collection system level, i.e., are all the vehicles collecting and transmitting data from both the CAN-bus and external sensors? Is the amount of data being collected and transmitted reasonable in terms of the expectations? The actual quality checking of the data, per se, was conducted by the quality checking algorithms of the WXDE and in the applications hosted at NCAR; namely, the Vehicle Data Translator (VDT), the Enhanced

Maintenance Decision Support System (EMDSS), and the Motorist Advisories and Warnings (MAW). In general, the data gathered in this project was of good quality.

4.8.4. Managing the Data

NDOT owns the data. As this is a pilot project and not a NDOT-wide operational deployment, the data goes to UNR; they process it (minimally) and from there it goes to the NCAR and WxDE servers. UNR is responsible for the data now but if the project moves forward into a production environment, it will be the NDOT's responsibility host and manage the data. NDOT pays for the data management; however, data collected by this project that resides at the NCAR or WxDE servers is paid for by FHWA. There is a Data Sharing Agreement with FHWA with no restrictions on the data use. IMO data is included with the RWIS data so there is no unique agreements for IMO data. The data has no personal identifiable information(PII) when it goes to the 3rd party servers, though there are vehicle unit numbers in the data stream when the data is collected and sent; this is not a problem, since the vehicles used are from the government fleet, the drivers are conducting official business, and they have no expectation of privacy when conducting official business on a public vehicle. This project endeavored to collect and transmit data in accordance to the existing applicable standards (SAE J2735, NTCIP 1204, SAE J1939, etc.) and also following the guidelines from the WxDE for the provision of metadata. Data transmission frequency was determined based on needs for forecast verification (forecast update cycle) and other application needs; every attempt was made at minimizing transmission latency and optimizing the probe message size.

4.8.5. Benefits for the Infrastructure Manager / Road Operators

Near-real-time weather, vehicle, and road condition data will be used by NDOT personnel to improve highway maintenance operations both in terms of increased level of service and cost savings through applications such as the Enhanced Maintenance and Decision Support System (EMDSS) and the Maintenance Management System (MMS). There is a great advantage in knowing the atmospheric as well as pavement surface conditions in near real-time in order to focus maintenance efforts on the trouble spots. Interfacing the onboard data collection system with the vehicle intrinsic systems (via the CAN-bus) and the retrofitted systems and sensors, allows for optimization of human and material resources use and for better awareness of vehicle maintenance needs.

4.8.6. Benefits for Road Users

All users of the roadway will benefit from this technology. The highly relevant data collected by these mobile data collection systems, (hyper-local and hyper-current), allows transportation officials to take maintenance actions or implement strategies to safeguard safety and mobility along the system. Additionally, the mobile data being collected, along with other traditional sources of data, is being used as input into value-added weather-related applications such as the VDT and the Motorist Advisories and Warnings (MAW) and relevant/actionable information is being made available to the system users for them to take appropriate action in real time.

4.8.7. Institutional issues or challenges

While this project was meant to be a prototype deployment of very limited scope, it brought to light significant challenges that an agency would need to overcome should they want to do a large scale, operational deployment. Education and training: buy-in from maintenance personnel would be a key ingredient to make such efforts successful. Operators would need to be educated on the value of these systems, i.e., how they can be used to better manage the transportation system and the resources; they also would need to be duly trained on the use of the technology. Some operators expressed a feeling that the AVL/GPS technology is just another way for administrators to "*micro-manage*" them, so these fears would need to be dealt with. Also, getting data from the CAN-bus has proven to be a very difficult task, i.e., collaboration from the vehicle manufacturers regarding the meaning of the data sourced from the CAN-bus interface has been very minimal; additionally, the CAN-bus data from a particular vehicle model isn't consistent from year to year (and much less across models and manufacturers). So, cooperation from the vehicle manufacturers and standardization of the vehicle data would be a big benefit for these types of projects. An agency considering large-scale deployment of these technologies also would need to be committed to making a sizeable initial capital investment as well as being committed to finance its adequate maintenance over the years. Some components of these systems may be proprietary and the agencies may also need to incur royalty fees as well as communication fees.

4.8.8. Lessons Learned

There is definitely a perceived value in the data and in the information provided by the value-added applications used in this project. These are complex, technology-intensive systems and applications. There is a need to implement robust data storage and management systems to handle the copious amounts of data generated by the mobile platforms. Communications pose a difficult challenge, i.e., for most weather-related applications, transmission latency is not an issue; that said, it is very important to be mindful of data packet size and transmission frequencies in order not to overwhelm your communication system. The technologies involved in these types of systems are also rapidly evolving. Therefore, it is important to design them with universality and inter-operability concepts in mind; not doing so, may render these expensive investments obsolete in a short period of time.

4.8.9. Future Works

The Nevada DOT IMO is an ongoing project. Lessons learned from the two initial phases of the project are being carried over into the 3rd phase (IMO 3). This 3rd phase is envisioned to go until 2018 and will involve adding Dedicated Short Range Communications (DSRC) to the communication platform; thus having a hybrid communication platform making use of 800 MHz radio, cellular communications, and DSRC. Data aggregation and overall management will eventually be transferred from the UNR servers to the NDOT servers; and the system needs to be optimized in terms of cost, versatility, configurability, etc. to make it affordable and scalable for fleet-wide deployment and tailored to the maintenance forces priorities and specific mission objectives.3.1. Tipo de tecnología

5. CONCLUSION

5.1. TYPE OF TECHNOLOGY

There is no "*silver bullet*" to address the technology needs of a transportation agency. The individual needs and context of each individual agency are going to drive the choices that are made regarding what communication platform or what specific application is used.

5.2. DATA QUALITY AND MANAGING DATA

As seen in most of the use cases presented, data quality is of paramount importance and proves to be a decisive factor in the project's success. The use cases also show that guidelines, policies, and perhaps even laws, regarding data security should be established and followed. Of particular importance is safeguarding the privacy of the drivers/data contributors. The connected vehicle world, with the inherent advancements in communication and sensing platforms, will result in enormous amounts of data being collected. Agencies need to be well provisioned for "*Big Data Management*" practices to ensure appropriate handling and use of the data.

It is important to recognize that "*universality of the data*" can only be ensured by institutionalizing strict measures of quality assurance, quality control, and by following the appropriate Standards. This ensures that data collected in one country could be used in a different country without much difficulty.

On the subject of data governance, it should be clearly understood upfront the roles and responsibilities of each of the parties involved, i.e., who owns the data, who is responsible for managing the data, what is the legal exposure of the participants, etc. These "*institutional*" issues should be understood and, to every extent possible, addressed in the early stages of any project deployment.

5.3. BENEFITS

One of the most obvious conclusions in the area of benefits is that all of the use cases will have a positive impact in at least one of the following areas: traffic safety, mobility, the environment, and agency efficiency; the use cases may also be of direct help to drivers and transportation managers. By helping the infrastructure owner to understand the driver behavior and driving style, as presented in the use case for the city of Eindhoven, Netherlands, they could provide the best warning solutions for the driver. Several of the use cases are about warning the driver of hazardous conditions ahead.

Many of the projects is about providing the infrastructure owner or the infrastructure holder a better opportunity to monitor the road construction.

As stated in the "*Mobile µTEC Road Surface State Sensor*" use case: "*The benefit for road users apart from the fact that critical road conditions can be treated more efficient and faster would lie in the better information before driving*" This is a quote that could be used for almost every single one of the use cases.

5.4. FUTURE WORK

Almost all the cases need to work with guidelines and legislation for the gathering of the data and also for the different uses of data. Standards are important in this stage of the development. To be able to learn from each other and use the same technic in different countries will be useful, and good for the future cooperation between the members of PIARC.

All of these cases are in the front of the technology-development, which probably means that there will be more of these kind of project in the future. Winter service and the management of the road networks during degraded conditions will be able to profit from the whole of these technological developments, for the analysis of the road surface qualities, the management of the interventions, the information management and more generally the traffic management.

6. GLOSSARY

- Intelligent Transportation System (ITS)
- (Road) Weather Information Systems ((R)WIS),
- Environmental Sensing Stations (ESS)
- vehicle to infrastructure (V2I)
- Infrastructure to vehicle (I2V)
- vehicle-to-vehicle (V2V)
- information and communication technologies (ICT)
- (Winter) Maintenance Decision Support System ((W)MDSS)
- On board diagnostic (OBDII)
- floating car data (FCD)
- European committee of road director (CEDR)
- Trans european network (TEN)
- Dedicated Short Range Communication (DSRC)
- Coordination and Implementation of Road Research in Europe (ERA-NET ROAD)
- Road state Monitoring System (ROSTMOS)
- Austrian highway company (ASFiNAG)
- Automatic vehicle location (AVL)
- Format of exchange of "road" data DATEX2
- public/private partnership (PPP)
- Traffic Data Warehouse (TDW).
- Closed-circuit television (CCTV)
- Dedicated Short Range Communication (DSRC)
- Road Side Equipment (RSE)
- Enhanced Digital Access Communications System (EDACS)

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