Vehicle Based Data for Road Winter Service

Overview of the Final Report to be delivered at the 2015 World Road Congress in Seoul, South Korea

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Introduction

This document is intended to be a “White Paper” outlining the principal focus areas of PIARC WG 2.4.3 report titled “Advanced technology for data collection and information to users and operators”, which is in progress and that will be presented at the World Road Congress in Seoul, South Korea in 2015. The report covers vehicle-based data (intrinsic, as well as from additional on-board sensing devices), collected in near-real time, and useful for road winter service related applications.

Use of vehicle based data has a huge, and still underestimated, potential for road winter maintenance. Unlike classic roadside monitoring devices, that are valid only for spot measurements, vehicles operating as active and mobile sensing units allow for capturing of a wide variety of data across the whole road network in a cost-effective way; the time and location-specific atmospheric and pavement condition data will be of great value, particularly when paired-up with the more traditional sources of information such as RWIS, radar, etc.

Industry continues to provide ever higher levels of vehicle automation with constantly growing amounts of embedded sensors and subsystems aimed at increasing vehicular safety and operational control. Moreover, the automotive industry continues to experiment with mechanisms to provide actionable feedback to the driver. Some of this feedback may be of advisory nature, providing decision assistance to the drivers, however, the vector of technological development is now moving towards adaptive solutions, providing full-fledged autonomous reaction of vehicles in safety-critical situations.

Concerning specific needs of winter road maintenance, meteorological and pavement conditions (also characterized by indirect parameters), captured by moving vehicles are of particular interest as additional input to decision-making support tools and traffic information services. The principal data flow for such implementations, where intrinsic data is processed by the OBD-II interface, fits the common ITS platform through the envisioned V2V and V2I communication systems. However, these are emerging technologies, and data reliability and interpretation are needed to be continuously tested and standardized. There still exist significant societal barriers, such as legal aspects of personal data usage; safety and security of the data and communication systems being employed; and a sound business model for system deployment still needs to be agreed upon. Therefore, pilot projects typically deploy only specific fleets, where the number of mobile probes is limited and carefully controlled.

The balance of this paper will highlight principal issues concerning vehicle-based data gathering and transmission technologies suitable for the needs of winter road maintenance as illustrated by a number of relevant case studies from different countries.

Background

Weather has a significant impact on the operations of a nation's roadway system year round. Water, in any state, reduces pavement friction. Winter weather, in particular, can leave pavements snow-covered or icy. Snow precipitation, fog, blowing snow, and vehicle spray can restrict visibility. Snow accumulation and wind-blown debris can cause lane obstructions. These winter weather events can result into changes in traffic conditions, roadway safety, travel-time reliability, operational effectiveness, and productivity.

Traffic conditions may change in a variety of ways; winter weather events may prompt travelers to change departure times, cancel trips, choose an alternate route, or select a different mode. Slick pavements, low visibility, and lane obstructions lead to driving at lower speeds or with increased following distances. These changes in driver behavior can impact the operation of signalized roadways, for example, where traffic signals are timed for clear, dry conditions, through reduced traffic throughputs, increased delays, and increased travel times.

Adverse weather affects roadway safety by increasing driver exposure to hazards and crash risk. Travel-time reliability for motorists and commercial vehicle operators is affected by a variety of weather conditions. Weather also impacts the operational effectiveness and productivity of traffic management agencies and road maintenance agencies through increased costs and lost time.

It is, therefore, an important responsibility of traffic managers and maintenance personnel to implement operational strategies that optimize system performance by mitigating the effects of winter weather on the roadways. The operational approaches used by these personnel dictate their needs for weather and road condition information. Accurate, timely, route-specific weather information sourced from mobile probes can have a dramatic impact on how traffic and maintenance managers operate and maintain roads under adverse conditions while allowing the regular commuter to make better informed decisions.

The Need for Change

Far too many lives are lost every year on the world's roadway systems due, at least in part, to the effect of adverse weather; additionally, material losses associated with the cost of fatal and injury crashes coupled with the loss of revenue resulting from impaired mobility on the roadway system far exceed any reasonable expectations.

As an example, an analysis of data compiled by the National Highway Traffic Safety Administration showed that on a fourteen-year average from 1995 to 2008 there were over 6,301,000 vehicle crashes in the United States each year. Twenty-four percent of these crashes, or approximately 1,511,000, are identified as weather-related. Weather-related crashes are defined as those crashes that occur in adverse weather (such as, rain, sleet, snow, high winds, or fog) or on slick pavement (i.e., wet, snowy/slushy, or icy). On average, 7,130 people are killed and over 629,000 people are injured in weather-related crashes each year. While these numbers are showing a downward trend, this is consistent with overall trends for all traffic fatalities and injuries.

Maintenance managers utilize road weather information and decision support tools to assess the nature and magnitude of winter storms, determine the level of staffing required during a weather event, plan road treatment strategies (e.g., plowing, sanding, chemical applications), and activate anti-icing/deicing systems. Traffic operation managers can make use of this highly granular pavement and climatological condition to modify phase and timing of signal systems, adjust the timing at ramp meters, make variable speed limit adjustments, etc. When this spot-specific and time-specific data is used as input to decision support systems, advanced traveler information, systems, and other transportation-related applications, the expected outcome are improvements in the areas of safety, traffic flow, travel-time reliability, and an increase in agency productivity.

Presently, the vast majority of regular commuters only benefit from the technological advances in vehicle telematics via generic information provided to them through dynamic message signs, radio messages, traffic condition reports obtained by phone (511 systems), etc. A time is soon to come, however, when the average commuter will receive relevant, timely, and specific information in the cab via a graphical user interface, or a personal communication device such as a smart-phone, or other media of their choice. The intent is to provide feedback to the vehicle operator through any choice interface that does not compromise safety.

While the traditional sensing devices that measure pavement conditions and climatological conditions near the roadway (such as the environmental sensing stations of an RWIS system) or the more remote systems that either directly measure or from whose data those conditions can be inferred, such as radar and satellites, have made great strides, they still lack the ability to provide roadway segment-specific information system-wide. It is broadly believed that vehicles serving as roving probes can satisfy this data gap.

The Technology Involved

Mobile sensing involves the integration of sensors and other systems onto vehicle platforms. In combination with vehicle location and data communications technologies, mobile sensor systems can be used to sense both pavement conditions (e.g., temperature, friction) and atmospheric conditions (e.g., air temperature).

The systems of interest, for the purposes of this paper, are those in which the mobile probe (or connected vehicle) acquires data from its native sensing devices (as provided by the original equipment manufacturer (OEM)) and makes that data available through the appropriate interface for the vehicle in question (CAN-bus or OBD-II); relevant data, and acceptable for the purposes of this work, can also be collected by external sensors retrofitted to the connected vehicle.

At a very basic level, the systems of interest for the purposes of this paper are comprised of: 1) the connected vehicle, with all the necessary sensing system interfaces 2) backhaul data communication system (in-vehicle and on roadside as appropriate) 3) value-added data aggregator or roadside data processing systems, as appropriate.

Fundamentally, the issue of interest is having the mobile probe data be part of an open loop system (a system that extends beyond the confines of the vehicle); where the data collected by the vehicle is sent to a third party data aggregator, value is added to the data, and actionable information is either relayed back to the vehicle operator in particular or to the community of drivers overall. Feedback to the particular driver can be on the form of advance warnings concerning potential threats laying ahead (slick roads, poor visibility, congestion, etc) and feedback to the general users can be in the form of messages displayed on changeable message signs, variable speed limits, traffic advisories, etc.

Use Cases

The primary focus of this effort is to illustrate the benefits of mobile data collection and transmission by means of a selected number of use cases. Regardless of the application being used, a demonstrated benefit to the individual roadway user and/or to the community of travelers must be ascertained. For the purposes of this paper, the assertion of the benefits of mobile data will “communication platform agnostic.” In other words, it irrelevant whether to communication is via dedicated short-range communication (DSRC), Cellular, high band radio, Wi-fi, etc.

Following are three use cases that represent the type of projects of interest to this work. More use case will be contained in the Final Report to be released at the 2015 World Road Congress in Seoul, South Korea.

Use Case #1

Integrated Mobile Observations (IMO) 2.0
Objectives
The IMO 2.0 project will achieve the following specific objectives:

- Advance the body of knowledge related to the capture and communication of vehicular and external sensor data that can be used by road weather connected vehicle applications
- Develop, test and evaluate the feasibility and effectiveness of road weather connected vehicle applications
- Support the National Highway Transportation Safety Administration (NHTSA) rulemaking decision (to compel automakers to make intrinsic vehicle safety-related data available) by providing the test environment for connected vehicle data that can be used by road weather applications

The findings and output of the IMO 2.0 project will be used to accelerate the adoption and effectiveness of road weather data in the context of other stakeholders, i.e., the benefactors of weather-related application outputs.

Participants
The USDOT has partnered with the Minnesota (MnDOT), Nevada (NDOT), and Michigan (MDOT) departments of transportation to execute the project. The three states have placed CANbus readers and external road weather sensors on their maintenance fleet vehicles to collect vehicular and meteorological data that could be used for evaluating road weather connected vehicle applications.

MDOT is instrumenting and deploying 20 snowplows and 50 light duty vehicles (pick-ups and passenger cars) with connected vehicle technologies. They created a smartphone application to capture and transmit the vehicular and external sensor data via cellular communications. MDOT will implement a weather information communications application.

MnDOT is instrumenting and deploying 305 heavy duty trucks (snowplows) and 30 light duty vehicles, and is using an Automatic Vehicle Location (AVL) type system to collect the data from the vehicles and then transmit it via cellular communications. They will implement and operate multiple applications (Enhanced Maintenance Decision Support System, Information for Maintenance or Fleet Management Systems, Records Automation, and Motorist Advisory Warning).

NDOT is instrumenting and deploying 40 vehicles (mix of snowplows, light duty trucks, and passenger cars). They created software to collect the data onboard the vehicles and then transmit the data using their statewide 800MHz radio system, as well as cellular communications. NDOT plans to develop and test an Enhanced Maintenance Management System application.

The data from all three states is sent to a Vehicle Data Translator (VDT) that checks the quality of the data and infers current and forecasted observations which, in turn, are used by the road weather connected vehicle applications. All three states will implement, test, and evaluate the selected road weather connected vehicle applications, and will contribute to measuring and quantifying the costs and benefits to be provided by the road weather applications. A benefit-cost analysis will support the NHTSA rulemaking decisions in fall 2013 and in fall 2014. The project is expected to complete in late Fall 2014.

Use Case # 2

Cooperative ITS Corridor Joint Deployment
Objectives

This project intends to demonstrate the benefits of vehicle communications (V2X); particularly vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V). The driver for the effort is the vision that safe and intelligent mobility can be realized by wirelessly connecting vehicles to one-another and to the infrastructure. This project is considered a field operational test (FOT) of the pan-European Cooperative Intelligent Transportation System.

Two cooperative ITS services are first planned for use in the Cooperative ITS Corridor Rotterdam-Frankfurt/M.-Vienna

- Roadwork Warning (RWW), which entails the provision of warning messages being sent to the driver from control centers via the roadside infrastructure
- Probe Vehicle Data, where vehicles transmit data about the current situation on the road to the roadside infrastructure and to the traffic control centers.

In both cases, communication from the vehicle and the infrastructure is established via short range communication (Wi-fi 802.11p, 5.9 GHz) or the cellular network (3G, 4G).

Participants
This is a collaborative effort between the European Union Countries of Netherlands, Germany, and Austria. "Cooperative ITS require the commitment of many partners from Many branches of industry and politics. The Amsterdam Group, a strategic alliance of road operators and industry on a European level, is coordinating the effort towards deploying cooperative ITS. Involved are CEDR as an organization of public road operators, ASECAP as an umbrella association of the toll road operators, POLIS as an umbrella association of cities and the Car2Car Communications Consortium representing the automotive manufacturers and associated industries. Completion of this project will be post 2015.

Use Case # 3

MOBI-ROMA
Mobile Observation Methods for Road Maintenance Assessments

Project Description
MOBI-ROMA develops and evaluates the benefits of the new satellite positioning techniques and operational concepts for road management assessment needs utilizing Floating Car Data (FCD). The concept is to combine and process available data from fixed measuring field stations and floating cars. The combination of different sources of data gives a novel opportunity for efficient monitoring and detection of variations in pavement and road conditions. This approach enables development of maintenance tools for road conditions during various times of the year and various traffic conditions. Data from the CAN-bus within the car are applicable as a quantitative basis for signal processing and analysis. The road parameters that can be estimated with the MOBI-ROMA method are for instance:

- Quality of the road condition
- Strength of road bed
- Need for winter maintenance

In order to demonstrate its applicability, a Graphical User Interface will be developed, and a pilot will be demonstrated in test areas in Sweden and Germany. The results will be evaluated carefully, and cost/benefit analysis made in order to assess the feasibility and benefits of these new methods in road maintenance.
The emergence of Global Navigation Satellite Systems such as GPS, Glonass and the coming Galileo has allowed the development of various new mobile observing techniques with

unprecedented spatial accuracy. The resolution of the new measurements may be 1000 times better compared to the conventional fixed network output. The method is expected to gain significant improvement of the management of the European road network in a very cost-efficient way. It will also take road management forward with a consistent and practical approach. It can be implemented for all types of road network all around EU where FCD or mobile observations are available.

The basic hypothesis is that in-vehicle information from the CAN-bus outlet provides several kinds of mobile observations that can be used in combination with data from fixed stations to assess road surface conditions and other parameters which are considered as important for road maintenance planning. This is possible since the variation of road surface conditions is related to the signal from the vehicle. A reference for modeling of corresponding relation is provided by the information from the fixed stations. After data fusion and analysis and effective dissemination of information through a Graphical User Interface, more comprehensive and timely information for road maintenance is provided.

It can be further hypothesized that information from normal car sensors can be refined to estimate the condition of a single road section. This will then be gathered from several cars to give estimate of the status of the complete road network. In a future system we foresee that it will be possible to follow the changes in the road network on a week to week basis.

Participants
This is a joint research program that was initiated by "ERA-NET ROAD II – Coordination and Implementation of Road Research in Europe" (ENR2), a Coordination Action in the 7th Framework Program of the EC. The funding partners of this cross-border funded Joint Research Program are the National Road Administrations (NRA) of Belgium, Germany, Denmark, Finland, France, Netherlands, Norway, Sweden, Slovenia, and The United Kingdom. Technical support is being provided by several private sector firms: Foreca Consulting Ltd, Klimator AB, Pöyry Infra GmbH. This project has been largely concluded.

Use Case #4
" 5.9 GHz Dedicated Short Range Communication Vehicle-based Road And Weather Condition Application."

Objective
The objective of this research project is to develop and test the acquisition of road and weather condition information from 5.9 GHz DSRC-equipped public agency vehicles; to transmit this data via RSE to a central server; and ultimately to make the data available to a number of data aggregation environments and value added developers for ultimate use by agency maintenance personnel.

The research system developed by this project will collect weather observation data from mobile sensors on transportation agency vehicles; transmit the data by way of DSRC roadside units (RSU) to one or more collection systems; and ultimately make the data available to other information systems such as the New York State DOT INFORM system and the U.S. DOT's Weather Data Environment. In this way, the additional weather information from mobile platforms will eventually enable traffic managers and maintenance personnel to implement operational strategies that optimize the performance of the transportation system by mitigating the effects of weather on the roadways.

Some of the anticipated benefits resulting from this project are:

- It will demonstrate key new capabilities to the advantage of all CV applications and deployers.
- It will confirm the results and experience with DSRC equipment and interoperability at similar installations (e.g., the Ann Arbor Safety Pilot).
- It will demonstrate operation of IPv6-based DSRC transactions within a heterogeneous IP network.
- It will collect a significant body of probe data using standard probe data messages.
- It will demonstrate and provide usable statistics on probe data collection over DSRC for use in follow-on performance assessments and requirements generation.

Participants

This project is being funded and administered by a consortium of US state departments of transportation, and led by the Virginia Department of Transportation. The Connected Vehicle Pool Fund Study, as the consortium is known, is supported by a team of private consultants.

Summary

By means of this white paper first and, ultimately, through the preparation of 2015 final report, Piarc's Technical Committee 2.4.3 "Advanced Technology for data collection and information to users and operators" intends to document the common issues associated with the deployment of connected vehicle technologies. After a brief discussion of these common issues, the final report will include a number of uses cases that will illustrate how agencies around the world are implementing connected vehicle technology to overcome challenges of particular interest to them. *It should be noted that the Use Cases presented in this preliminary report are just for illustration purposes, i.e., presented as examples, and they may or may not be included in the final report. The final report will contain detailed information regarding each use case.*

Little argument can be made that the technical issues associated with V2V, V2I, and even vehicle to pedestrians (V2P) have largely been overcome – at least from a theoretical standpoint, since the robustness of systems under very large penetration conditions (thousands or even hundreds of thousands of connected "entities") remains to be tested. Of much greater concern are the policy and institutional issues associated with the deployment of connected vehicle technologies. In this regard, many questions come to mind: what is an appropriate business model to deploy a system like this that equitable to all those involved (the public sector, private industry, and tax-paying commuters)? What are the necessary measures that need to be taken to develop a robust communications platform that is safe, secure, and respectful of citizen's personal information? What measures need to be taken to standardize data, equipment, and interoperability? Who owns the data? Who is legally responsible when things go wrong? ….

While the final report will not provide definite answer to these questions, it does intend to have a general discussion so as to inform the readers about them.

References

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