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LOW COST ITS – CASE STUDIES

TECHNICAL COMMITTEE B.1 *ROAD NETWORK OPERATIONS / ITS*

WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE
AIPCR PIARC

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 2016– 2019and 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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1. V-TRAFFIC : THE TRAFFIC INFORMATION SERVICE FROM MEDIAMOBILE

Authors: J. Ehrlich and P. Goudal (France)

The development of telecommunication networks opens up new possibilities for the collection of traffic and mobility data. V-Traffic is a set of traffic information services provided by Mediamobile, a company based in France, specialized in aggregating travel related information from different sources. The collected data allows to produce real-time road traffic information and travel services such as real-time road weather conditions, air quality information, availability of electric charging stations and parking spaces, petrol and road toll pricing and more. First, the case study describes the process of collecting data from several sources and the various communication media used. Then the question of quality control is addressed and it is described how it is handled by Mediamobile. The issue of heterogeneous data fusion is a challenge that is also being addressed. Finally, the economic model is briefly discussed. The study concludes with some perspectives for the future.

2. VAO - TRAFFIC INFORMATION AUSTRIA

Author: Dieter Hintenaus (Austria)

Multimodal journey planning tools have been on the European agenda for several years. Austria took the approach to develop a platform called VAO („Traffic information Austria“): a nationwide intermodal traffic information platform that integrates approved traffic information for all modes of transport (incl. road, rail, cycling, walking) provided by the major traffic infrastructure and traffic service providers. In case of public transport information, this information is even based on real time data (including delays etc.) for various operators. VAO has successfully implemented a high-quality intermodal routing application that is used by partners and business-to-business (b2b) customers to create powerful end user applications.

VAO is a cooperation of Austria’s major traffic infrastructure, traffic information and transportation providers. It has been designed to be extensible and full functionality was achieved in 2014.

3. AUTOMATIC WEATHER DETECTION USING CCTV …

Full title: Automatic weather detection using CCTV video images for discrimination of driving condition on Korean Expressway

Author: Namkoong Seong J. (South Korea)

Yungdong Expressway, one of the Korean expressways with a total length of 234km, connects Seoul, the capital city of South Korea, with the eastern cities of the country. Since it is constructed through a mountainous region, the road weather conditions can be very fickle. With the Pyeongchang Winter Olympics in Jan. 2018 approaching, road safety is now more important than ever for the IOC and the Korean government. A real-time notification system that alerts the drivers of the current weather condition is useful but limited due to financial implications arising from pan-highway installation of AWS[1]. Thus, we have established a system that utilizes pre-installed surveillance CCTV cameras to observe and report on the weather.

This paper proposes the technology of weather detection using CCTV systems already installed on roads. Recently, CCTVs can be considered 'intelligent,' since they already have image-processing technology and multi-surveillance functions (i.e. traffic information gathering, incident detection, weather detection, etc.). Thus, no new equipment investments are needed for monitoring purposes, making this technology very cost-effective. Intelligent CCTVs, which have been operating for a long time, collect a large amount of data, which can be analyzed and used for forecasting information for a specific location - for example, weekly or monthly pattern analysis of traffic information, incident analysis, weather forecast etc. We attempt to improve road safety with intelligent CCTV.

4. Connected citizens program's (CCP) platform ...

Full title: Connected citizens program's (CCP) platform as a value added tool for the exchange of traffic data between Waze and road authorities worldwide

Author: Jelisejevs Boris (Latvia)

The CCP is an ongoing partnership (initially launched in late 2014.) between Waze and various public road authorities to share incident and road closure data. Now, more than 50 public partners have joined the CCP worldwide. Within the CCP, Waze provides real-time, anonymous, incident and congestion information directly from the drivers (Waze users). Public partners provide both real-time and advance information on their construction, crashes and road closures. The CCP is especially effective in areas, where Waze is popular and its users provide a dense coverage of real-time probes to describe traffic patterns and give direct feedback on traffic problems encountered on a trip. The aggregated Waze data are usable for both planning and real-time management tasks. Many specific (distinctive) case studies within CCP already exist. For instance, Latvia uses it to share direct driver alerts to Waze users. The CCP is a practical example of a public-private partnership in ITS to reach higher data use within society while avoiding excessive investments.

5. Japanese C-ITS "ETC2.0 multi-application project" using 5.8GHz DSRC

Author: Makino H.(Japan)

In 2014, Japan introduced the ETC2.0 OBU that was developed as V2I cooperative ITS initiative. It employs a 5.8GHz DSRC communication system that allows high speed, large capacity communication between vehicles and infrastructure. The ETC2.0 OBU also enables collecting probe data on travel times and behavior through the use of GPS functions in addition to basic applications such as Electronic Toll Collection (ETC), safe driving information provision, and dynamic route guidance. As of August 2016, one million vehicles have been equipped with ETC2.0.

In considering a V2I cooperative system deployment strategy, road administrators need to initiate developing roadside infrastructure first (e.g. roadside units). Then, the costs for operation and maintenance can be covered using toll revenue. Moreover, it is effective to disseminate onboard units with toll discounts to road users, taking advantage of the lower toll collection costs.

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[1] AWS = Automatic Weather System

The ETC2.0 OBU has secure communication based on the DSRC security platform, and it uses a basic application interface that combines numerous common functions, enabling the use of various ITS services. Therefore, the ETC2.0 OBU can provide various applications such as Electric Toll Collection (ETC), traveler information delivery to vehicles and probe data collection at low cost. Currently, new applications are being developed for freight operation, heavy vehicle traffic management by road administrators that have additional benefits for road management. We will discuss those case studies in the full paper.

6. Electronic Toll Collection (ETC) in China

Authors: LI Bin and LIU Hongwei (China)

Since the first expressway was built in 1995, China kept a rapid development speed in eatablishing the whole expressway system, with the legal requirements of toll collection on this enclosed-type system. With the development of socio-economic and transportation demand, a significant problem on the low efficiency at manual tolling started to appear gradually. In order to solve this, China begun to research and developed the double-chip mode Electronic Toll Collection (ETC) system since 2000, which fully suit to the domestic situation, and the system were implemented in most provinces in a few years. From 2007 to 2012, with a system of uniform standards, demonstrations on ETC cross-provinces networking operation were carried out in the Beijing-Tianjin-Hebei area and the Yangtze River Delta area. And in 2015, China finished the ETC networking operation throughout the whole nation, which means ETC users could travel in the expressway system without stop by one single ETC card, and this brought a significant increase in user amount and a booming in ETC industrial growth. By the end of 2016, the total user amount of ETC exceeded 35,000,000.

7. Travel Time estimation with Bluetooth technology

Author: Hamid Torfehnejad (Iran)

The RMTO (Road Maintenance & Transportation Organization) has implemented a project to estimate the Travel Time (TT) over the intercity roads. In this project we have installed some road side units to collect the smart phone MAC addresses (SPMA). These units will collect the SPMA of each device inside the vehicles with Bluetooth turned on. The SPMA road side units are installed at 2 points with enough distance between. The data will be gathered in a center and used to calculate the time between the two collection points. As we know the exact distance and the calculated time between two points, we can calculate the travel time for each vehicle. By averaging the travel time for an appropriate number of vehicles, we can estimate the Travel Time between two mentioned points. This project has shown that an approximately 7% penetration rate of vehicles with active Bluetooth devices is enough for calculating an average travel time.

The drivers before the first data collection point on the road will be informed of the TT by Variable Message Sign (VMS).

This is an example of Low Cost ITS implementation because we don't pay any cost for the smart phones. The smart phones belong to people using the roads and are the main objects to produce vehicle probe data. We just collect the data using some road side units with a Bluetooth receiver.

We do not track specific smart phone location information via the BTS[2] network as we have governmental restrictions on gathering this kind of information.

In the full text proposal of case study, we will compare the implementation cost of this method with some other older methods for TT estimation and will have more discussion about the cost and the benefits.

8. Providing Traffic Information through Public-Private Partnership

Author: Hidenori Yoshida (Japan)

A Japanese mobile information terminal software company and road information board manufacturer established a specific purpose company (SPC) to provide traffic congestion information through a Public-Private Partnership (PPP) model by contracting with road administration for ITS equipment operation.

In this system, road administrators can provide users with information about road work, congestion, etc. on variable message signs (VMS). They collect road traffic data in urban areas using traffic counters with cameras, analyze it and provide congestion information by VMS. To cover the operational and maintenance costs, the operator displays sponsors' advertisement on half of VMS through the PPP. As a Coporate Social Responsibility (CSR) activity, the space for advertisement is sometimes used for public message purposes such as messages to improve driving manners.

9. Freight/Public transport management …

Full title: Freight/Public transport management by adding value to existing systems/frameworks

Author: Hidenori Yoshida, Asuza Goto (Japan)

This case study summarizes the example of a low-cost approach for adding additional services to an existing freight/public transport management service. This approach is low cost in that it makes use of existing system/frameworks (e.g., infrastructure, regulations, communication network) to provide new services.

For example, in Thailand, the government requires bus and truck operators to install an onboard GPS tracking system. A Japanese service provider developed a system that adds various applications using telematics for real-time communication and an onboard digital tachograph. This system promotes more efficient truck operation by supporting safe driving, prevents fuel-theft by drivers using liquid surface sensors in the fuel tank, etc. These applications enable truck operators to reduce costs enough to cover the initial costs and maintenance costs. In addition, by sharing probe data with other companies, more complete traffic information can be obtained at no additional cost. In Japan, field operational tests were conducted for a logistics management service by providing private companies with the ETC2.0 data. MLIT[3] originally collects this data for road management. This service is another case that utilizes an existing framework for probe data collection to develop additional applications.

[2] BTS = Base Transceiver Station
[3] MLIT = Ministry of Land, Infrastructure, Transport and Tourism

10. Principles for Disaster Control in ETC2.0

Author: Yuji Ikeda (Japan)

Understanding road traffic condition in disaster-stricken area using probe data has been recognized as important since the Kumamoto Earthquake in Japan in April 2016. This case study introduces the challenges to utilize probe data for disaster recovery in Japan, and principles for disaster control in ETC2.0 probe system.

11. Bluetooth Sensors for Traffic State Estimation and Automatic Incident Detection on Freeways

Author: Martin Margreiter (Germany)

This case study describes an example of a low-cost ITS application based on the use of Smartphones and Bluetooth connectivity for estimating travel times and assessing traffic conditions. Smartphones are identified by their MAC address collected through the Bluetooth link. Thus, vehicle transit times are recorded at various points on the network, making it possible to estimate travel times by aggregation. The case study describes the difficulties encountered, particularly because of privacy constraints. The main results of the evaluation are given.

12. Low Cost ATIS of Korea, Traffic Information Service using Navigation Data Thru Private and Public Partnership

Authors: Keechoo Choi, Seong J. Namkoong, Yongju Yi (Korea)

The purpose of this case study is to introduce the current method of extracting link travel times using probe vehicles based on a partnership between private and public sectors in Korea and to spread this concept to other countries as a low cost ITS ATIS services. The cases study also includes the evaluation of the quality of both public and private traffic information in such a manner that possible problems in using the combined information can be minimized. Criteria to evaluate the quality are introduced and this paper also tries to suggest a way to improve the current model to improve accuracy, completeness and coverage etc.

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Low Cost ITS (France)

1. V-TRAFFIC : the traffic information service from MEDIAMOBILE

Keywords	V-TRAFFIC : the traffic information service from MEDIAMOBILE
Authors	J. Ehrlich (IFSTTAR), P. Goudal (MEDIAMOBILE), France
Reviewer	Fritz Busch
Translator	N/A
Date	February 2014

1. Context, objectives

The development of telecommunication networks opens up new possibilities for the collection of traffic and mobility data. V-Traffic is a set of traffic information services provided by Mediamobile, a company based in France, specialized in aggregating travel related information from different sources. The collected data allows to produce real-time road traffic information and travel services such as real-time road weather conditions, air quality information, availability of parking spaces, petrol and road toll pricing and more. The company provides services for over 20 European countries, either directly or through partnerships with local operators.

2. Technical aspects/challenges

Mediamobile is in charge of the collection of raw data, the data enrichment, publishing and distribution of the refined traffic information. The information originates from numerous sources: speed measuring sensors, data collected from public or private road operators, over floating car data from over one million vehicles and more than 20 million mobile phone users. The data is aggregated on an in-house platform and formatted to V-Traffic mobility services for distribution to vehicle navigation systems, traffic monitoring tools, radio, TV and web interfaces and more. V-Traffic historical traffic flow data can also be used to understand, anticipate and quantify household mobility or driver behavior for example. Urban development, zone planning or logistics are just some of the application areas.

3. Services

V-Traffic provides various services. Depending on the country, European drivers can benefit from the following services:

- Traffic flow information: actual travel speed on all major roads,
- Traffic events: alert for accidents, roadwork and road closures,
- Dynamic routing and estimated travel times,
- Road weather events: slippery roads, heavy rain and snow alert,
- Animals warnings : sections of roads where wild animals are likely to cross,
- Touristic events : sports events, concerts etc. that may impact on traffic and parking availability,
- Police controls

4. Broadcasting protocols and medias

Broadcasting modes (Figure 1) vary depending on receiving platforms: in-vehicle GPS, smartphones and other mobile devices, internet, digital signage screens, television, etc.

- Information delivered to autonomous GPS or in-vehicle navigation system is mainly broadcasted using TMC (Traffic Message Channel) technology via the radio RDS (Radio Data System) signal.
- Some embedded navigation systems make use of a “connected” data link provided by mobile communication technologies. This technology requires the installation of a SIM card in the in-vehicle device that performs traffic information reception. More efficient than RDS-TMC in terms of transmission frequency and granularity, connected services present several drawbacks: a high cost and unstable reception in poorly covered areas or when the mobile network is saturated.

Figure 1 - Main channels for information distribution

- The most efficient broadcasting based on digital radio DAB is being experimented in France (cities of Marseille, Nice, Paris). Other countries like Germany, the United Kingdom, Norway, Poland and Denmark are more advanced than France regarding the deployment of DAB, which offers a data capacity more than 400 times higher than the more traditional RDS-TMC technology. Thus digital radio allows providing richer and more accurate information. It can be presented to the driver in numerous different ways, such as text messages, images, maps or text-to-speech.
- Media services for Radio, TV, web and digital screens rely on an internet connection for delivery or data and images.

5. Quality control

Coverage, freshness, accuracy, detail and how it matches the driver’s own observations, are decisive factors in the user’s satisfaction and trust in his navigation equipment. The quality control approach is based on the driver’s real world experience. Mediamobile uses multiple methods to continuously measure and compare traffic info:

- In-house Test Drives made by professionally trained Mediamobile staff. It includes track validation, and individual and subjective observations.
- Competitive Test Drives based on independent auditing of several devices ((PNDs, Smartphone or built-in solutions) in parallel, and perfectly equal conditions.
- Continuous Quality Monitoring by comparison between broadcasted information and floating car data fleets samples. Provides a 24h, network-wide quality metric.
- Employee Involvement through incentive schemes, where all Mediamobile’s employees are committed to report detection errors for continuous improvement.

To estimate the quality level, different metrics are used:

- Event detection: true detection (QKZ1 indicator) of a jam & false alarms (QKZ2 indicator),
- Speed Flow information: reported speeds compared to actual speeds, true detection and false alarms applied to travel times,
- Routing: Estimated Time of Arrival: Difference between estimated travel time and the actual time to reach destination (%); Fastest Route Calculation: The order of arrival and the timing of arrivals,
- Source Coverage: The percentage of time the system reported a flow (regardless of accuracy), including loss of RDS / GSM signals).

Mediamobile has developed specific tools for measurement, visualization, comparison and analysis of the quality of its traffic information. As an example, Figure 2 (left square) shows the spatiotemporal graph of a wide jam moving backwards. Here, the red color of the track indicates the driver entered the jam before it was reported by Mediamobile (QKZ1) and that the driver escaped the jam earlier than reported (QKZ2).

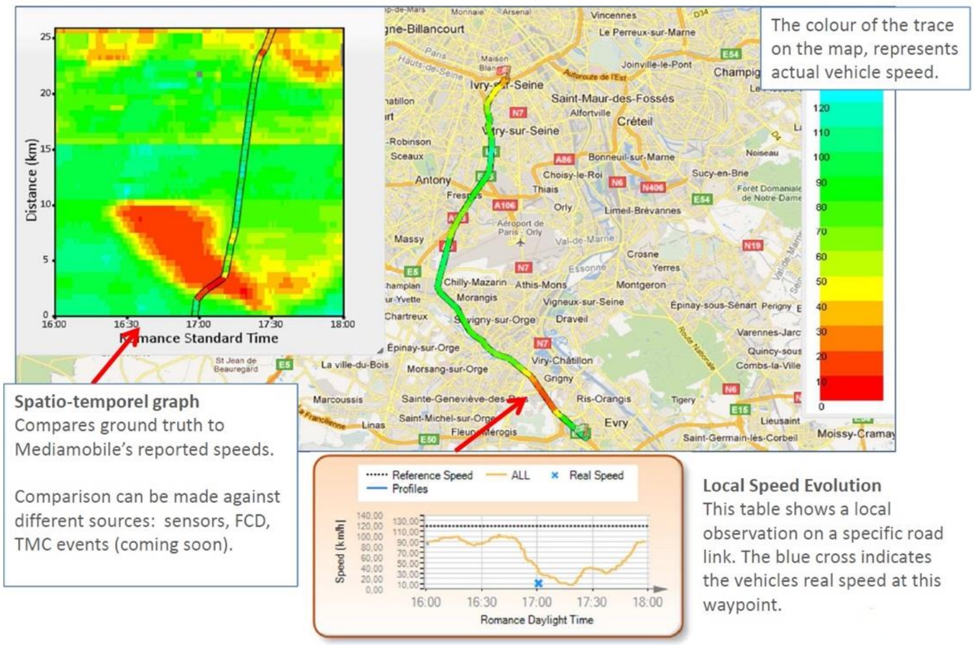

Figure 2 – Quality Viewer

6. Non technical aspects/challenges

One of the main challenges is collecting and merging data from a wide variety of sources that come from public authorities or private sector. The service implements algorithms taking into account the real-time data but also calendar data and statistics to provide estimates of changes in the short term (H + n) and the long term (J + n).

As each provider uses its own geographic reference, traffic data must be translated into a common reference. Similarly, as each provider has its own frequency of information update, the data must be synchronized in time. When multiple data sources coexist, specific processing is made to improve the final information.

Therefore V-Traffic services are the result of a value chain (Figure 3) where every step is mastered by Mediamobile: from the collection data from data providers, dealing with telecommunication/broadcasting operators, to distribution to cars manufacturers, equipment suppliers (navigation system, in-vehicle radios etc).

Figure 3 – V-TRAFFIC value chain

7. Business model

To ensure its sustainability, the service delivery must be based on a viable business model. When services are based on DAB or RDS-TMC broadcasting technologies, the automakers include access to the service in the selling price of the receiving equipment. In this way, the unique contribution is not noticeable as such by the final customer. Oppositely, connected services are most often paid directly by the consumer, first by paying a subscription to the access to the 3G/4G networks, as well as fees for accessing selected subscription based services (3,59 € on AppStore in May 2014).

8. Test/Evaluation

As a member of TISA, the Traveller Information Services Association, Mediamobile supports standards that provide elements or a framework for services and products covering traffic and travel information such as RDS-TMC or TPEG protocols.

Future

Mediamobile recently opened an office in Stuttgart - Germany - emblematic city of the German automotive industry - to be closer to the leading manufacturers and suppliers of the industry in Europe. The ambition is for Mediamobile to be the leader on Traffic Information supplier on DAB thanks to the technological transition from analogue radio to digital radio. Thus, Mediamobile already launched its services V-Traffic DAB in some European countries. The company also supports its partners present in the UK, Benelux and also in Italy, with the goal of providing the best and most comprehensive DAB-TPEG traffic information service in Europe.

Contact/Further information

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Jacques Ehrlich, IFSTTAR, France, jacques.ehrlich@ifsttar.fr

References/links

[1]	V-Trafic website : www-traffic.com
[2]	Mediamobile website : www.mediamobile.com
[3]	"A statistical framework for road traffic prediction", Guillaume Allain - Mediamobile, proceedings of the ITS World Congress, 2009, Stockholm, Scientific Session IS31, Paper 3714
[4]	"« QUality Assessment of Travel Times for TRaffic Operation and Information Services » (2010-2012 QUATTRO project, AIT Austrian Institute of Technology GmbH, Bernhard Heilmann, Transnationale Projekte, Austria)
[5]	« Mediamobile approach to Quality », Philippe Goudal – Mediamobile, ITS WC2012, 5th NEARCTIS Workshop, Vienna
[6]	« CO-DRIVE - Co-Pilote pour une route intelligente et des véhicules communicants » (2010-2014 FUI R&D project, MOVE'O + System@tic + Véhicule du futur labels, Valeo, Philippe Gougeon, France)

Low cost ITS (Austria)

2. VAO - Traffic Information Austria

Keywords	
Authors	**Dieter Hintenaus**
Reviewer	**Kian Keong, Andrzej Kobuszewski**
Translator	
Date	**January 2018**

1. Description

The European Commission passed the Delegated Regulation (EU) 2017/1926 on 31 May 2017 with regard to the provision of EU-wide multimodal travel information services.

Even long before this event Austria took the approach to develop a platform called VAO („Traffic information Austria“): a nationwide intermodal traffic information platform that integrates approved traffic information of all modes of transport (incl. road, rail, cycling, walking) provided by the major traffic infrastructure and traffic service providers. In case of public transport information this information is even based on real time data (including delays etc.) for various operators. VAO has successfully implemented e.g. high-quality intermodal routing that is used by partners and business-to-business (b2b) customers to create powerful end user applications.

VAO has started as a cooperation of Austria’s major traffic infrastructure-, traffic information- and transportation providers. It has been designed to be extensible and full functionality was achieved in 2014. The system includes public transport timetables, stations and other connecting points, a detailed intermodal graph, traffic messages and Level-of-Service data for all major motorways, all addresses in Austria, park+ride and other parking facilities as well as additional data such as points of interest, bike rental stations and short term parking zones. VAO’s various services rely on data covering all of Austria, making it a comprehensive toolset for traffic information and end user services. Intermodal routing services are available through a well-defined XML interface.

It is a common agreement that VAO is not a data platform and will not provide raw data for business partners. Instead, VAO provides routing services for b2b applications.

2. Objectives

The vision of VAO: The platform will always be free for private use and shall provide b2b services with a high quality and service level at marginal costs. The corporation will operate as a non-profit company and partners have agreed to invest in the unit as it shall be a public service.

Already in the early stages of VAO Austria has agreed to follow strictly the rule of “services instead of data”. The success of VAO proves the strategy right. In 2014 and 2015, various end user applications which rely on VAO as their backend and use the traffic information services have been published.

Currently, there are about 35 applications (Web and Smartphone Apps), which generate over 13 Million unique user routing requests per month. A growth rate of more than 100% - from 67 million routing requests in 2016 to 135 million in 2017 shows the still rising public interest.

Current applications based on VAO:

- VAO provides a ready-to-use journey planning website. It is hosted on VAO web servers and plugged with the routing engines. The service also provides a mobile version optimized for smaller screen sizes.
- First MaaS (Mobility a s a Service) application like WienMobil from Upstream GmbH are using the VAO to create a single booking platform that allows end users to book tickets for their intermodal journey in the simplest way. It works by providing a single harmonized access and charging system for public transport, rental bike and taxi cabs.
- In 2014, the federal ministry of finance developed a "commuter cost calculator" based on VAO to calculate tax credits and tax allowances depending on home and working location, work hours and available public transport connections.
- MORECO is a decision support calculation tool for citizens that includes residential costs as well as daily travel costs.
- The application "Radlkarte 2.0" provides bike routing services with specific information for cycling.
- The project "Ways4Me" developed a navigation app for disabled persons.
- The Austrian Ministry for education, science and research developed a calculator for fellowships for Austrian students in dependence of the distance from their family home to the city of their university.

3. Technical challenges

The main challenges of VAO are not in the field of technical issues as it uses mainly existing tools and data sources comprise sensors that are not just installed for the main benefit of VAO but for operation purposes of the transport operators. Hence, VAO may be regarded as a low-cost application in the field of ITS with a high benefit for end users.

4. Non-technical challenges

The main challenge in the phase of setting up the VAO was the organisational part of bringing all stakeholders on one table as well as to achieve a common understanding of the vision of VAO.

In 2013 an operational unit has been founded through operation contracts by six partners: BMVIT (the federal ministry of transport), ASFINAG (Austrian motorway operator), ARGE ÖVV (Austrian public transport associations), ITS Vienna Region, the federal state of Salzburg and ÖAMTC (Austrian Auto Touring Club). These partners provided manpower, technologies, hard-and software, licenses and funding for the interim operation of VAO.

In 2014 these partners agreed upon the foundation of a VAO corporation in order to professionalize the operation of the platform and assure long term funding. This main goal came into life in 2015 as has so far proven to be an international role model for providing multimodal routing services.

5. Evaluation

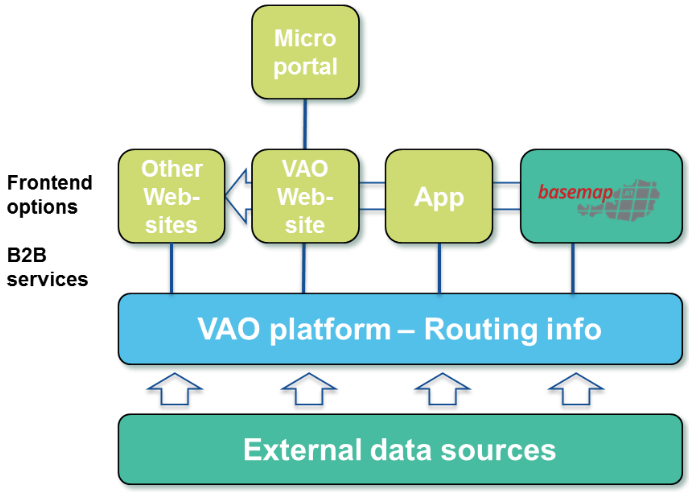
Due to the fact, that VAO is in operation and constantly adapted to the users needs, there was no evaluation necessary so far.

6. *Future*

VAO continuously aims at improving its service portfolio. The running project EVIS-AT (Real time traffic information on Roads in Austria) aims at providing real time traffic information for roads – based on the positive experiences on the motorway network. This projects brings aboard the Austrian federal states and therefore improves the importance of VAO´s services significantly. The project will end in 2020 and it is the common agreement to develop results that will start in daily operation of high quality services right after the project.

Further information

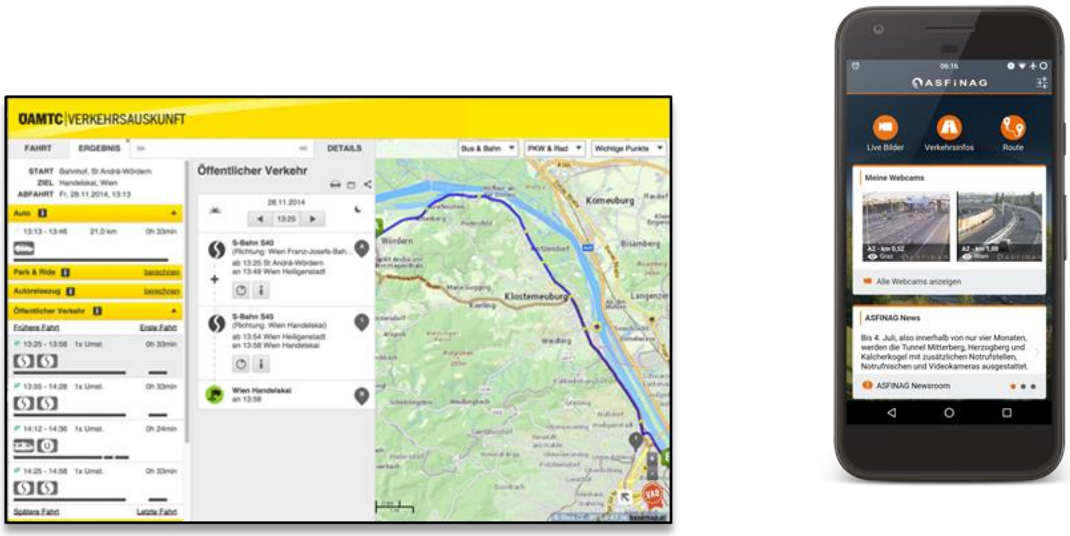
www.asfinag.at/en, www.verkehrsauskunft.at, www.anachb.at



External data sources:

- GIP - detailed graph of complete road network incl. traffic signs
- Addresses, POIs
- Public transport tables
- Traffic messages
- Video cameras
- Level-of-service data
- Park&Ride + other parking facilities
- Short-term parking zones
- Bike rental stations

Basic principle of VAO



Examples of applications based on VAO

Low cost ITS (South Korea)

3. Automatic weather detection using with CCTV video images for the discrimination of the driving condition on Korean expressways

Keywords	**Automatic Weather Detection System(AWS), CCTV, Image Processing Technique, Deep Learning, Machine Learning, Video Weather* Information System**
Authors	**Seong J. Namkoong, Joonyoung Min, Keechoo Choi**
Reviewer	**Jacques Ehrlich, José Nirina Andriannarivelo**
Translator	**N/A**
Date	**April 30, 2018**

1. Description

- (Case Study) Weather detection via CCTV has been implemented during Winter Olympic games during February 9 – 25, 2018, and Paralympic Games during March 9 – 18, 2018.
- We have collected video images from 74 CCTV spots on Youngdong Expressway, from Yeoju to Gangneung, which is 139km long.

2. Objectives

- For more effective monitoring of weather reports, it is recommended to have Automatic Weather Systems (AWS) installed every two kilometers of road, unless mass installation of AWS is financially impossible.
- Our research proposes a technology using CCTV systems already installed on the roads to monitor weather conditions. It also introduces a case study of an alternative weather detection system called VWIS (Video Weather Information System), which does not require investment on new equipment and, thus, saves cost. (i.e. cost savings effect and low cost ITS)
- A real-time notification system that alerts the drivers of the current weather condition is useful but limited due to financial implications arising from pan-highway installation of AWS. Thus, we have established a system that utilizes pre-installing surveillance cameras to observe and report on the weather.
- 200 km cost comparison example:
  - AWS based
    - If new installation is needed every 2 km on a 200 km road
    - Need 100 sets
    - Total cost: about 10 million USD (100,000 USD per set)
  - CCTV based
    - Pre-installed CCTVs every 2 km of road.
    - New devices not needed
    - Total cost: 0.5 million USD (5% of new AWS cost)

3. Technical challenges

- CCTVs are the most prevalent devices and will grow in number every year.

- Though the cost of CCTV installation is high, CCTV images are not very effective. Most CCTV images rely on the operator's visual monitoring. Furthermore, in Korea, the CCTV images are stored (or recorded) for 30 days maximum, by law because of personal information protection act. But this situation is very wasteful and inefficient
- All significant data and information, such as traffic information, accidents, and weather, must be extracted from CCTVs.
- By the Road Traffic Authority Reports Korea, 2011 ~ 2013 the traffic accident have been increased under bad weather condition, especially remarkably increasing by 10.6% under fog weather as shown in Fig. 1.
- Weather reports currently provided by the Korean Meteorological Administration (KMA) include weather conditions of discrete regions. As a result, current weather reports include information on not only the heavily populated areas most affected by dangerous weather changes, but also areas that are irrelevant to the weather conditions being reported. This technology reports weather conditions using roads (linear units) as basic units of weather observation, rather than areas.
- CCTVs can be considered 'intelligent' since they already have image processing technology and multi-surveillance functions (i.e. traffic information gathering, incident detection, weather detection, etc.). Thus, no new equipment investments are needed for diverse monitoring purposes (i.e. cost savings effect)
- Intelligent CCTVs which have been operated for a long time collect a large amount of data, which can be analysed and used for forecasting information for a specific location, for example, weekly or monthly pattern analysis of traffic information, incident analysis, weather forecast etc.
- We attempt to improve safety on the road with the intelligent CCTV
- We established the standard with KMA in order to verify the system performance. The rain and snow weather is divided into three levels according to measure of AWS, light/medium/heavy and the distance of visual range is used in RWIS data. Each level is as follows.

Table 1 Standard for verifying the system performance

Weather	Standard Device	Range	Level
Fog	RWIS	1 ~ 0.5Km	Light
		>> 0.5 ~ 0.2Km	Medium
		Under 0.2Km	Heavy
Rain	AWS	3mm/hr	Light
		3 ~ 15mm/hr	Medium
		Over 15mm/hr	Heavy
Snow	Measure	Under 1cm/hr	Light
		1 ~ 3cm/hr	Medium
		Over 3cm/hr	Heavy

- The verification calculations are various, one is the Accuracy (ACC), others are Probability of Detection (POD), False Alarm Ratio(FAR), Post Agreement(PAG), etc. The popular ways of those calculations are ACC and POD. ACC and POD is calculated by following equation respectively.

$$\mathrm{ACC} = \frac{H+C}{H+M+F+C} \quad \mathrm{POD} = \frac{H}{H+M}$$

Where, H means Hits, M is Misses, F and C is False Alarms and Correct negatives respectively.

- So we have shown the verification results of ACC and POD calculation in Fig.3. As our results, the fog detection from CCTV images have higher accuracy than other weather condition.
- One of the biggest advantage of fog detection from CCTV is the fact that it is higher accuracy than RWIS, exclusive weather information device. That means RWIS is not needed where CCTV is installed.

4. Evaluation

- South Korea held the Pyeongchang Winter Olympic Games 9-25. Feb. and Paralympic Games 9-18 Mar., 2018.
- We have supported Youngdong Expressway weather information services for public using VWIS from 05. Feb. to 18. Mar. 2018.
- During the 2018 Winter Olympic games, we were able to get over 95% accuracy in fog and snow detection (no rain as it was winter). As a result, we successfully proved prove enough CCTV's performance in weather detection system.
- Though CCTVs are not exclusive devices for weather detection, they provide very reliable information on the road weather. Field tests show 90% reliability from CCTVs, and the performance was especially good for fog detection.
- The verification calculations are various, one is the Accuracy (ACC), others are Probability of Detection (POD), False Alarm Ratio(FAR), Post Agreement(PAG), etc. The popular ways of those calculations are ACC and POD. ACC and POD is calculated by following equation respectively.

$$\mathrm{ACC} = \frac{H+C}{H+M+F+C} \qquad \mathrm{POD} = \frac{H}{H+M}$$

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- So we have shown the verification results of ACC and POD calculation in Fig.3. As our results, the fog detection from CCTV images have higher accuracy than other weather condition.
- One of the biggest advantage of fog detection from CCTV is the fact that it is higher accuracy than RWIS, exclusive weather information device. That means RWIS is not needed where CCTV is installed.

5. Future

- We will find a method to collect the weather information from CCTV at nighttime because all vision systems have a fatal weakness in darkness.
- We have plans to expand beyond expressways to freeways and local roads.
- We will develop exclusive hardware device including the detection of road surface condition (wet, snow or black ice) via a camera. If this system will be extended the service to whole

expressway, we have to develop the hardware to be installed each CCTV, because the network cannot covered thousands of gigabyte of image data from CCTV.

6. *Further information:*

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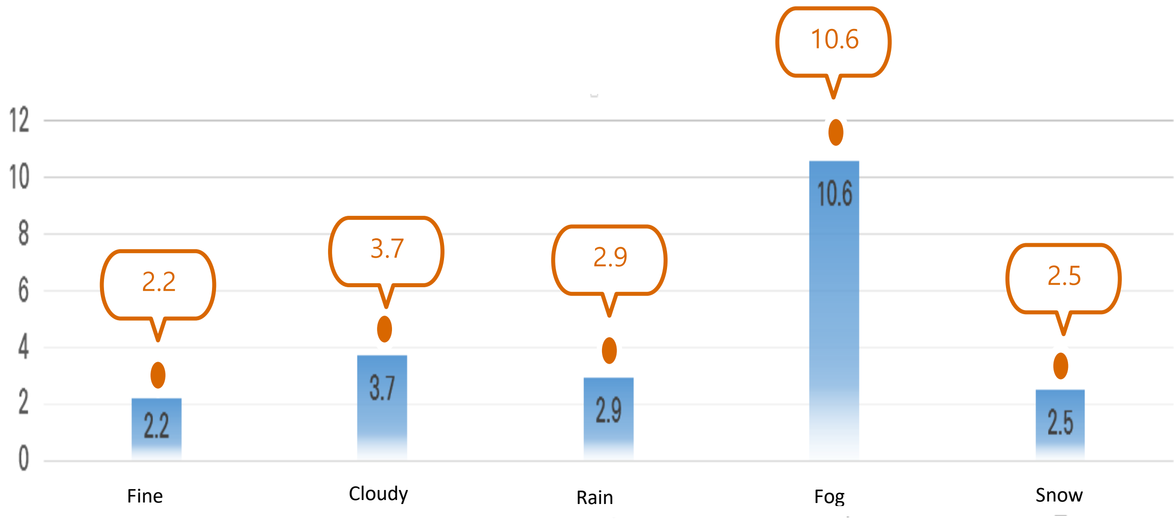


Fig 1. Traffic accident ratio under weather condition, 2011 ~ 2013 (Source : The Road Traffic Authority Reports, Korea)

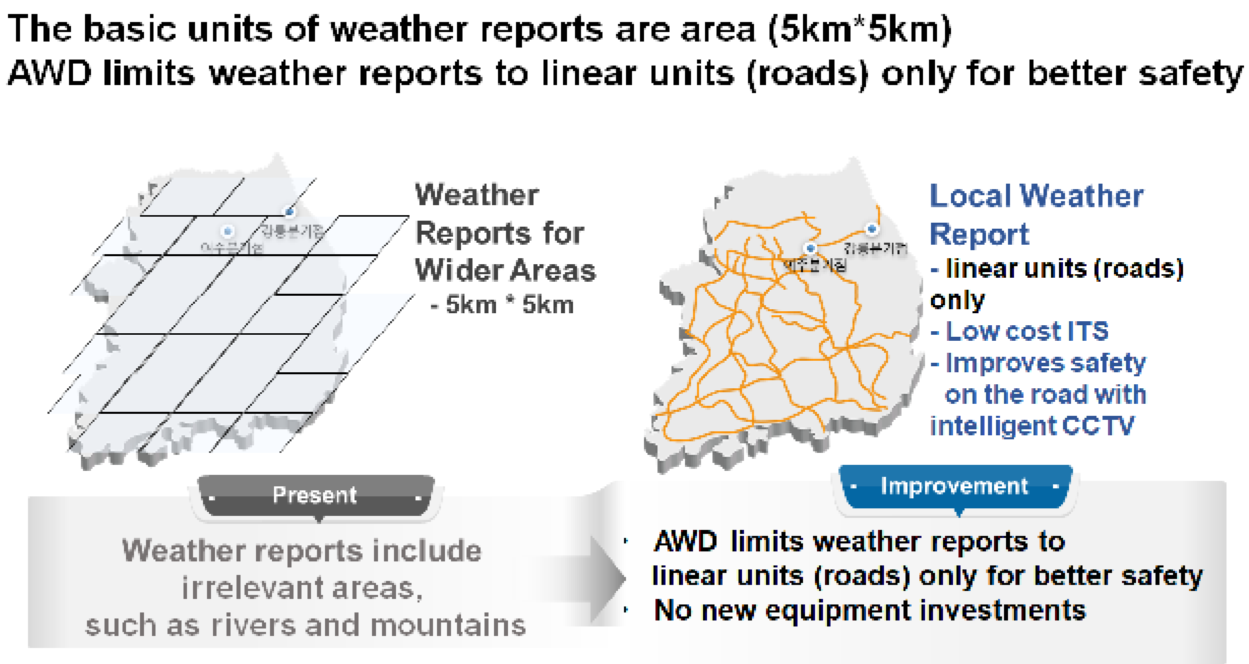


Fig.2 Changes to local weather reports, linear units along the roads.

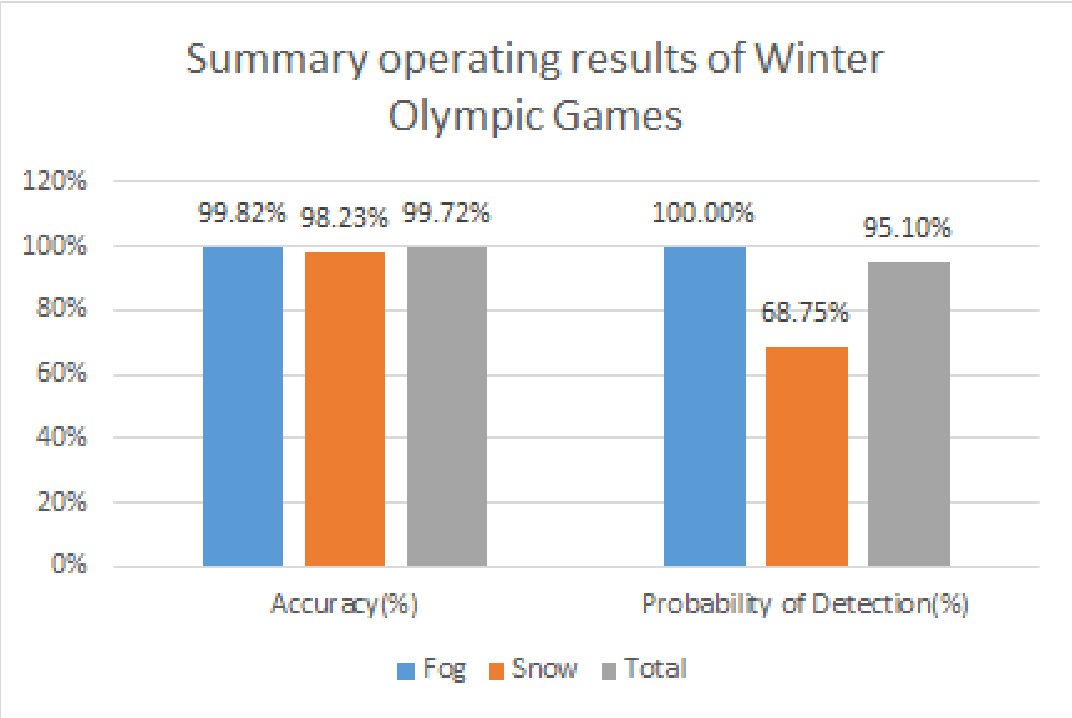


Fig.3 Summary operating results, during trail period 2018. Feb.05 ~ Feb.25, Winter Olympic Games

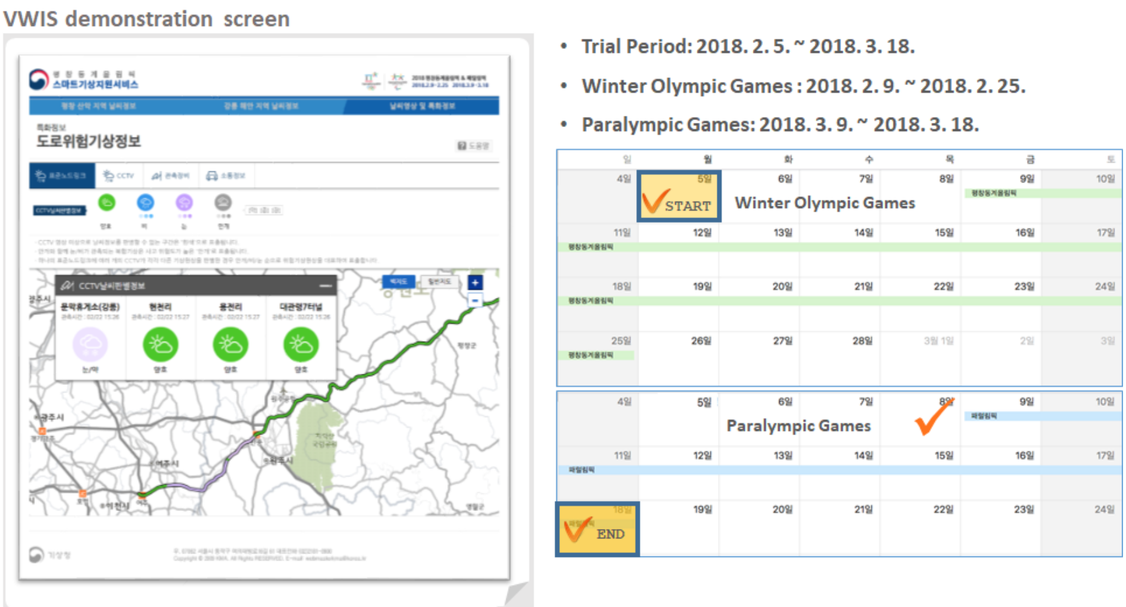


Fig.4 VWIS demonstration screen and schedule for trial period of Winter Olympic Games

- South Korea held the Pyeongchang Winter Olympic Games 9-25. Feb. and Paralympic Games 9-18 Mar., 2018. The IOC and Korean government must be fully ready for safety, so we have supported Youngdong Expressway weather information services for public using VWIS.
- Fig. 4 shows the example of demonstration screen, snow is shown in light violet on the map, fog in gray, and the clean weather was shown in green.

Fig.5 PC and Mobile Service screen

Fig 6. Operation in TMC during Winter Olympic Games

- Several cases

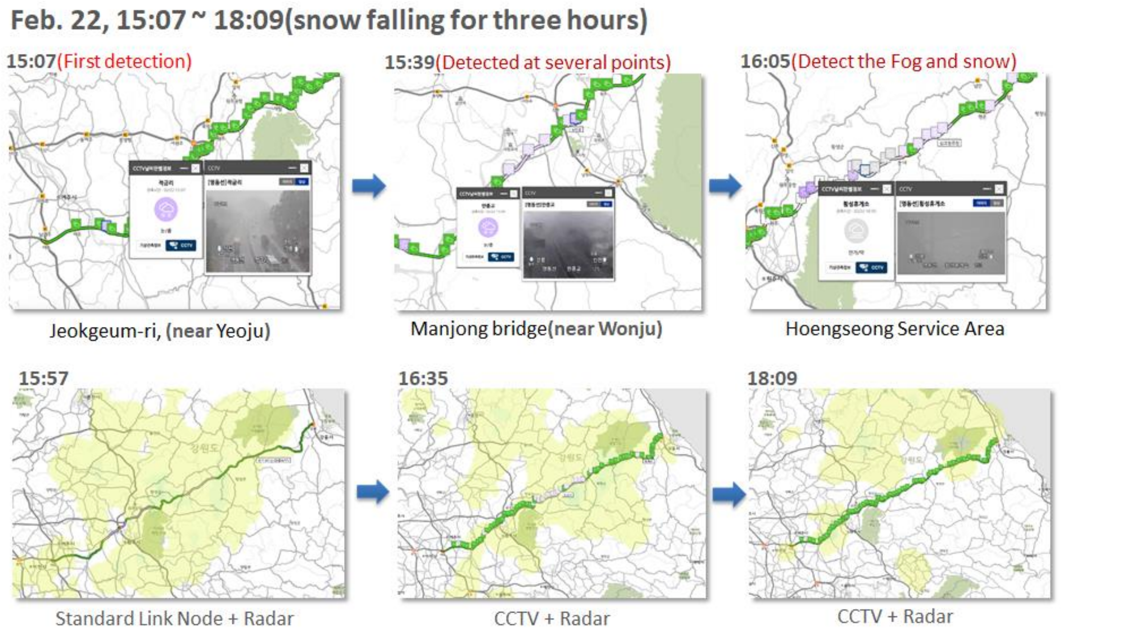


Fig 7. Feb.22, 15:07 ~ 18:09 Snow falling cases, lower pictures are illustrated a composite photograph of standard link node and radar

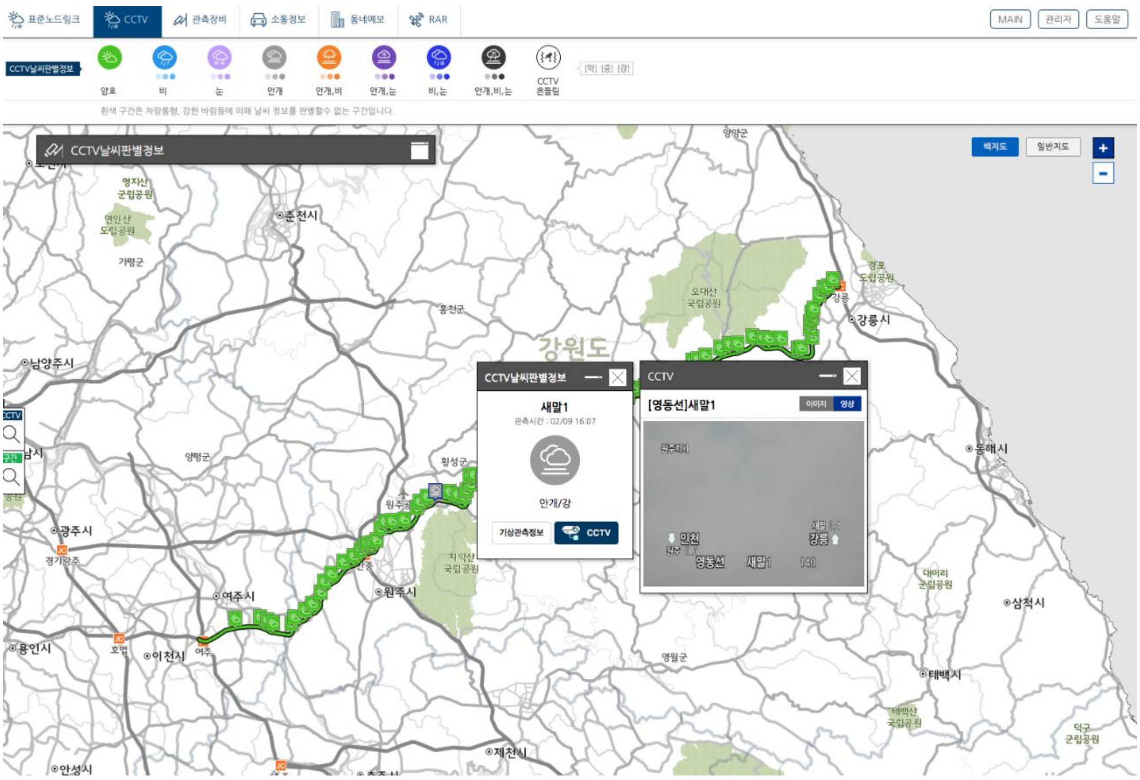


Fig 8. Feb.09 16:09 Deep fog case at Saemal IC

Fig 9. Feb.24, 07:24 Light Snow case at Kyohang-ri

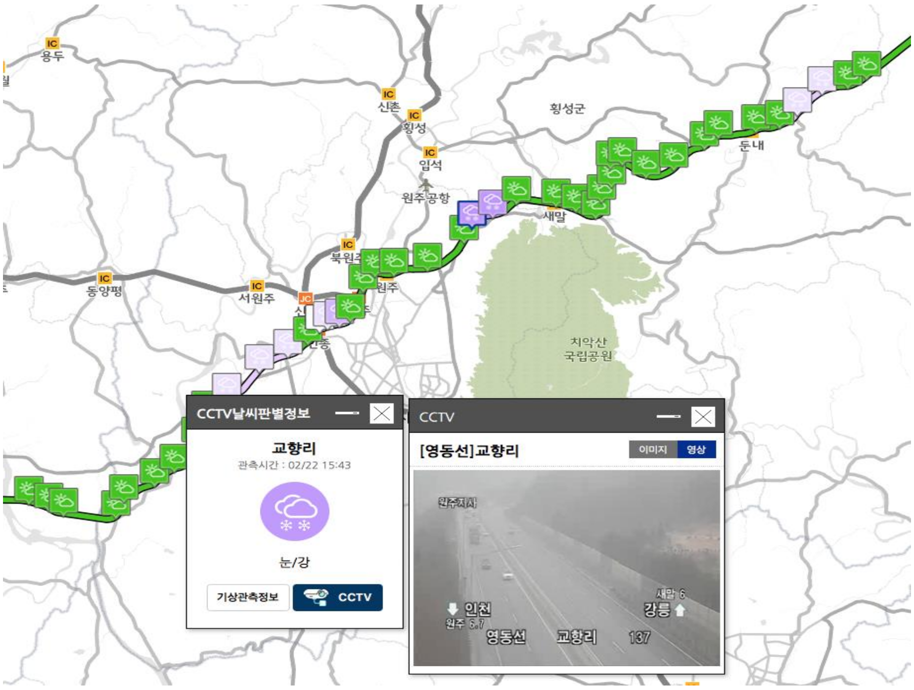


Fig 10. Feb.22, 15:43 Heavy Snow case at Kyohang-ri

Low-cost ITS (Latvia)

4. Connected citizens program's (CCP) platform as an added value tool for traffic data exchange between road authorities and Waze service worldwide

Keywords	**Traveller information, real-time navigation, big data, mobility oriented social media, smartphones' application, public-private partnership, global coverage**
Authors	**Boriss Jelisejevs**
Reviewer	**Paul Warren, Keechoo Choi**
Translator	**N/A**
Date	**May 2018**

1. Description

The CCP is an ongoing non-commercial two-way partnership (initially launched in 2014.) between Waze (smartphones' app, owned by Google since 2013.) and various public road authorities, aimed to exchange traffic incident and road closure event data. Now, more than 450 public partners have joined the CCP worldwide and thematic scope of the shared data and cases grew strongly. Several partners have shown, the procedure can be successfully applied for specific purposes, such as support of mobility related large-scale events and crisis response. Within the CCP, Waze provides real-time, anonymous, proprietary incident (users' reports) and slow-down (FCD) information directly from the drivers. The public partners initially aimed to provide real-time and advanced official information on their traffic restrictions and road closures. New data types can be integrated into the platform, when the need has been raised and agreed between the partners (the main reason is a request for such available data by Waze users). For example, the latest area of interest in Latvia is a mobile zones of traffic restrictions (e.g. winter service and routine maintenance actions).

The CCP is effective tool in the networks, where Waze is popular, and its users provide a dense coverage (mainly urban areas) of real-time probes to capture traffic conditions and give a direct feedback on traffic problems, identified during the trip. Aggregated Waze data can be also used for road network planning and management tasks. Several specific (distinctive) case studies within CCP already exist. For instance, Latvia uses it to share direct driver alerts and seasonal reminders to Waze users. The CCP is a practical example of simple private/public partnership relationship in the field of ITS. It demonstrates how this approach can be applied to reach higher data usability within society and reduce investment when compared to traditional data collection methods.

The Partners can use the following interfaces for data exchange, provided by Waze:

- live feed API (proprietary schemes by JSON or XML), suitable for circular well-described or automated data;
- data input directly into the Waze road closure tool (desktop-like web application) by traffic information managers available for both the Partner's data management and network-wide area Waze data monitoring;
- emails, that are quite adequate in untypical cases (traffic announcements, clarifications etc.);

- any combination of the above (probably as a complex or additional info), also to Waze local community members (enthusiasts attracted by Waze, regularly working for traffic information editing).

As far, as automated data transfer interface between Waze and the Partner is established, no more significant operational efforts and expenses are for the Partner to keep CCP on-going. Partners have access to an increasing amount of Waze specific tools, usable also in network operations (for example, „Waze-o-meter“ – professional dashboard-like web application for real-time and the aggregated historical traffic congestion data).

Latvian national road administration has joined CCP in 2014. Stable bilateral data flow is established there. Some specific things covered by the program here are related to winter traffic information (actual driving condition, machinery on route) and sharing general traffic notifications to drivers (seasonal or event - related).

2. *Objectives*

CCP is an example of a initiative to link app's provider and service users with official bodies (network operators). This is non-commercial partnership, where all the involved parties have certain benefits by kind of win-win principal, respectively:

- service provider (Waze) attracts more official traffic data to its platform, this improves existing services and paves the way to the other services and their commercialisation issues;
- Waze users get additional traffic information and better real-time navigation service precision, their feedback goes directly to official bodies and can be used to augment existing traffic information;
- network operators (as partners within CCP) benefit from additional traffic data dissemination channel and the respective crowd-source data enriches their operations;

Although CCP related general traffic data scope is quite simple, operational synergy is generated there for quite specific and untypical purposes. Good point is still growing extent (by number of the partners and a scope of related data) of such partnership, giving opportunity for best practice exchange. A recent feature is the introduction of traffic information campaigns and announcements (e.g., seasonal announcements about mandatory use of winter tyres), that expands Waze functionality (email notification service).

Despite of CCP is established for routine traffic information on daily basis, such unique tri-party communication might be the right choice for very specific and urgent traffic-related situations, experienced worldwide. The one group is related to the temporary big events (official visits, concerts etc.), to be managed thoroughly. The another one – crisis management, whereas Waze shares the important information to public (for example, operational status of gasoline stations).

The scope of the CCP partners is broadening, as many of smaller ones (rural municipalities, regional transport agencies) rely on their data sharing to the bigger ones (national road administrations), officially joined CCP. The last trend is also joining of regional media (mainly radio stations) to CCP, who're interested in broadcasting of traffic information, using Waze "live map" dashboard.

3. Technical challenges

The main challenges are related to a coherence (compliance) with formal regulations. Since CCP is distinctively voluntary form of cooperation, many points are still not formalised or need the process to be developed. By the way, Waze can incorporate highly specified data feeds from the Partners (e.g. Datex II).

CCP is continually developing, related data specifications will evolve, as well. A sound approach expanding from simple to increasingly complex data schemes that will retain flexibility not offered from legacy solutions.

4. Non-technical challenges

There are a number of challenges around the stability of business model (as Waze app is for free and no service charge collected) and long-term sustainability of service, as this fully reliant on Waze. It seems, some officials want increase control within CCP and periodically negotiate for that. The partnership would be equal until there is no conflict of interest. A typical example could be the Police might be unhappy sharing (by users) locations of traffic speed enforcement cameras or a network operator want to disseminate some specific info, that might be more PR, than traffic oriented. In such cases Waze always looks from the users' perspective or its own business logic. That's why, traffic data input to CCP is a rapidly deployable solution, and however it should be properly combined with alternative services (including public traffic information broadcasting).

Talking about gaps, some partners are faced with long response time on any untypical initiative (e.g., area-wide thematic traffic notifications). Maybe, this is because of only one global back-office, approving and implementing all CCP related tasks. Waze is actually working on expanding its community (regional enthusiasts, who are privileged users with extended rights to edit the content and direct communication to the back-office), which seems to be one more stable contact point within the Program.

5. Evaluation

A key element of Waze service is quality evaluation of content by its users (rating system for the events and users, posted them). As the app is based on crowd source data, quality control and content management procedures are strongly proprietary. Still growing dynamics of active Waze users is quite representative general self-evaluation of the service performance. But it's clear, Waze and CCP evaluation differs, as far CCP is trying to be moved towards bigger process formalization by Partners.

So, CCP provides features that complement the typical tools of public traffic control centres. It is accepted that CCP is not self-sufficient for all network operator needs and to be used as a widening of the classical approach.

6. Future

Waze and its add-on CCP faces growth in popularity in areas, where are no traffic information services. Service concept is easy to understand and acceptable for public. Following technological trends, Waze has ambitions to expand and take market shares from professional navigation services.

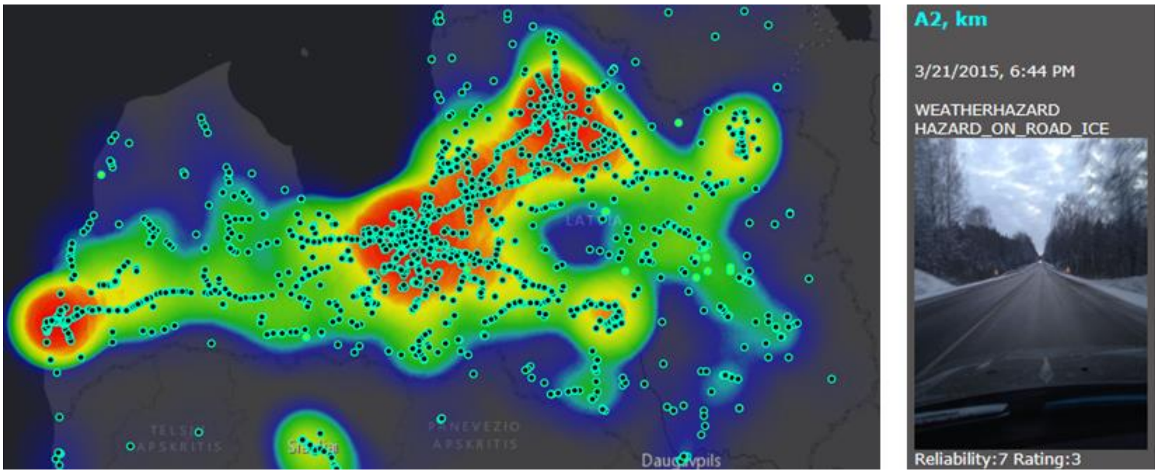
As Waze is a part of global corporation Alphabet (Google), all the related app's data are already or planned to be involved in in-direct commercialisation processes (big data analytics, modular services etc.). Looking from the perspective of co-operation with official bodies, Waze should develop and formalise rules and technical statements, related to CCP framework.

Further information:

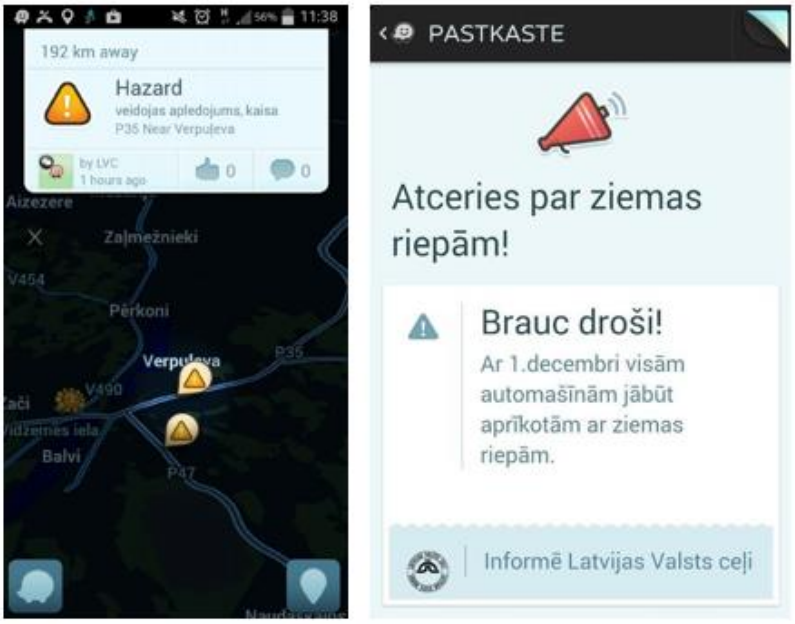
www.waze.com/ccp

Basic principle of CCP (Waze leaflet)

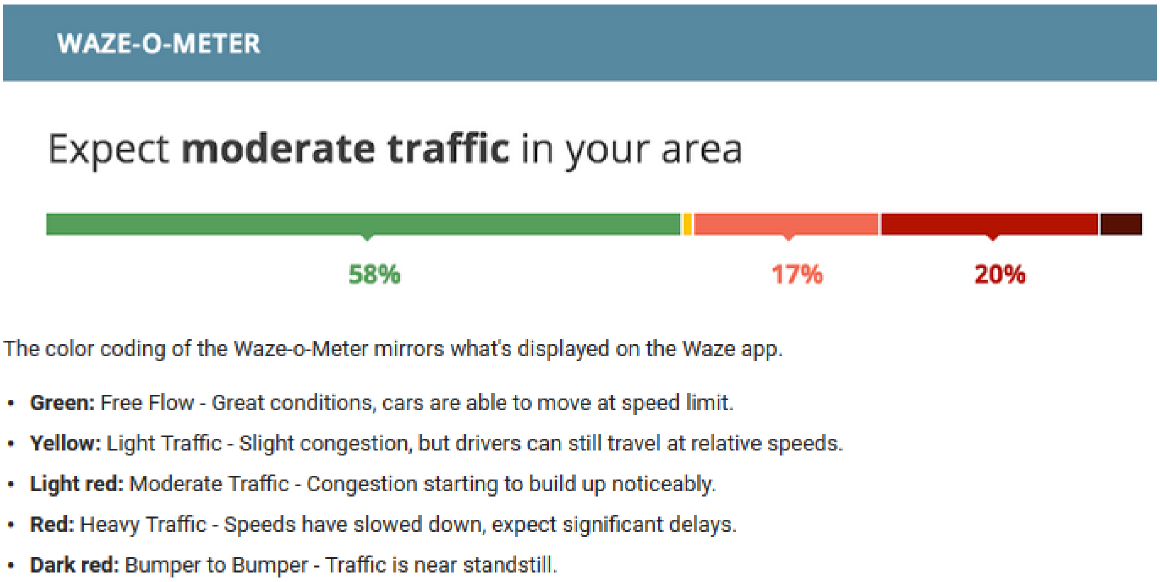
In-app (users oriented) response and network-wide (partners oriented) content management



Heatmap and multimedia package on users' traffic hazard notifications (theme: slippery road)



App's screenshots with the Partner's data (left - winter fleet on route, right – info campaign)



Waze-o-meter: the tool for monitoring of traffic conditions

Low Cost ITS (Japan)

5. Japanese C-ITS "ETC 2.0 project" for multi-application by 5.8GHz DSRC

Keywords	**Cooperative ITS, Electric Toll Collection, Information Provision, Probe Data Collection**
Authors	**Hiroshi MAKINO, Hidenori YOSHIDA**
Reviewer	**Seong J. Namkoong, Jacques Ehrlich**
Translator	**N/A**
Date	**2/7/2018**

1. Description

Japan has developed and put into practice the "Smartway", which is a system to integrate people, roads and vehicles with the use of leading-edge ICT (information and communications technology). The world's first V2I (cooperative vehicle-infrastructure) service was started in 2011, and which is currently called as "ETC 2.0".

"ETC 2.0" was advanced from the existing Electronic Toll Collection (ETC) system, which had been already deployed nationwide in 2001. It has enabled a variety of applications through high-speed and high-capacity communications between on-board unit (OBU) and roadside unit, thus could contribute to alleviating urban traffic problems. Basic functions of the ETC 2.0 are toll collection, information provision, and probe data collection (Figure 1).

2. Objectives

In order to solve urban traffic problems, the ETC 2.0 provides several benefits for drivers and road administrators.

Benefits for drivers are as follows:

ETC

- Time saving when passing through tollgates of expressway due to its nonstop payment system

Information Provision

- Reduction of accident risk by utilizing information and warning for traffic ahead (e.g. accident prone locations such as sharp curve, congestion after the curve)
- Avoiding congestion by congestion information
- Toll discount using route information

Benefit for road administrators are as follows:

ETC

- Congestion alleviation at tollgates of expressway due to its nonstop payment system
- Reduction in operational costs by reducing the number of toll collecting staff

Information Provision

- Accident reduction by informing and warning drivers of traffic ahead (e.g. accident prone locations such as sharp curve, congestion after curve)
- Congestion alleviation by providing congestion information, which can also leads to the reduction of environmental load

Probe data collection

- Stable supply of probe data with the specifications determined by road administrators at no cost; in other words, it is no longer necessary to purchase probe data from private sector with their arbitrary specifications and price every year.
- Collection of behaviour record data (i.e. sudden braking, sudden steering) that other types of probe data such as the one from smartphones would hardly obtain. By analysing those data and extracting hazardous locations, measures (e.g. road improvement) to reduce accident risk can be implemented effectively and efficiently.
- Using the probe data, it is possible to understand traffic conditions and identify locations which have some problems. After implementing some measures against the problems, it is also possible to verify their effects using the probe data.

3. Technical challenges

1) **Toll collection**:

- The ETC 2.0 enables to introduce a system to support different kinds of payment systems: fixed toll, distance-based toll and other toll systems according to routes, periods of time, traffic congestion condition, etc.
- The ETC 2.0 employs the two-piece system in order to accommodate various types of users. That means, an OBU contains vehicle information and an IC card contains personal data. This makes it possible for toll payer to be different from vehicle owner. Thus, vehicles except for privately owned ones such as rented cars can pay by using ETC as well.

2) **Information provision**:

- The ETC 2.0 uses the active DSRC (Dedicated Short Range Communications) in the 5.8 GHz band to provide information. Accordingly, high-speed and high-capacity communications enable to provide information for supporting safe driving, wide-area traffic congestion information of approximately 1,000 km ahead, and disaster information, etc.

3) **Probe data collection**:

- Two-way communications also allow for road administrators to collect probe data from vehicles recorded by on-board GNSS positioning functions. Probe data contains travel record and behaviour record. Roadside units have been installed on expressways and national highways considering the memory capacity of the OBUs:

  - Travel record includes time, position (longitude and latitude), and speed which are stored every 200 m, or every 45-degree change of driving direction with the maximum data memory for about 80 km.
  - Behaviour record includes time, acceleration, and speed which are stored when acceleration exceeds the threshold value (0.25G) with the maximum data memory for 31 points.
- Considering the privacy protection when collecting the probe data, the system makes it impossible to identify individual vehicles by deleting the data around 500 km from the locations where vehicles turned on/off their engines, as well as by changing vehicles' specific IDs every day, based on the ISO 24100.

4. Non-technical challenges

In order to make V2I systems low cost, it is necessary to create willingness to pay for both road administrators and drivers, since they need both infrastructure and OBUs.

Regarding the infrastructure, an effective way is to install it under the direction of the public organizations, and to ensure the toll revenues to repay the operational and maintenance costs of such facilities. In Japan, ETC has been widely used since 2001. Because ETC 2.0 was introduced with the existing infrastructure of the ETC as a basis, its initial costs were not so high. Considering the various additional applications and great extensibility in the future, high cost-performance was expected by the road administrators.

Regarding the OBU, although drivers are initially required to purchase it when using ETC 2.0, they do not have to pay communication cost afterward unlike smartphones. In addition, they are eligible for toll discount as well. Actually, the toll discounts were important to make drivers willing to pay for OBUs, which could be done by the reduction in operational costs for toll collection.

5. Evaluation

The benefits for drivers are the most important in order to promote the introduction and deployment of the ETC 2.0, since it is up to drivers whether they purchase OBU or not. As a fact, as of May 2018, 2.78 million of the ETC 2.0 OBUs have been purchased in Japan, with the increase of more than one million from the last year.

In recent years, use of the probe data is increasing when road administrators take measures for alleviating congestion, improving road safety (Figure 2), etc.

6. Future

Taking advantage of the ETC 2.0 as a V2I (cooperative vehicle-infrastructure) system, NILIM is conducting a public-private joint research project for next-generation C-ITS in order to expand the services: for example, "look ahead information (LAI)" provision service and merging support service on expressways.

Further information:

ITS-TEA. ETC Portal site (http://www.go-etc.jp/english/etc2/information_service.html)

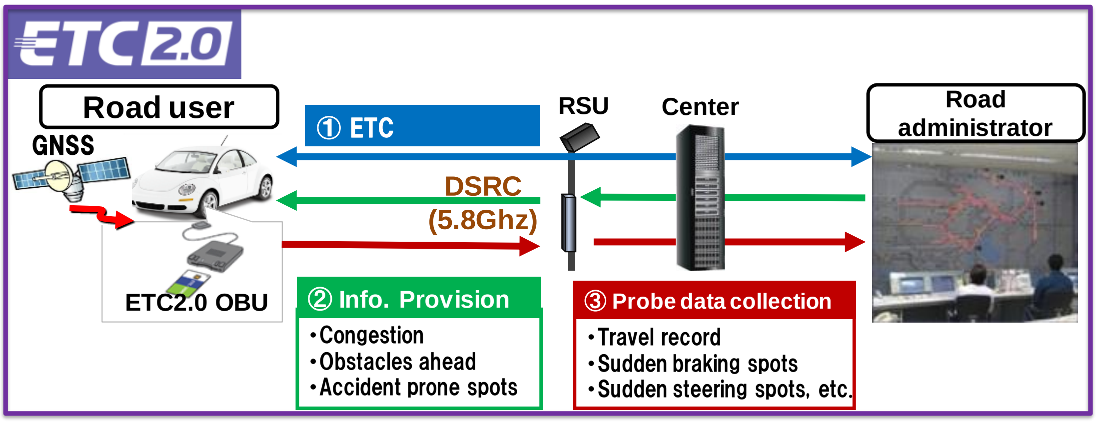


Figure 1. System outline and basic functions of the ETC 2.0

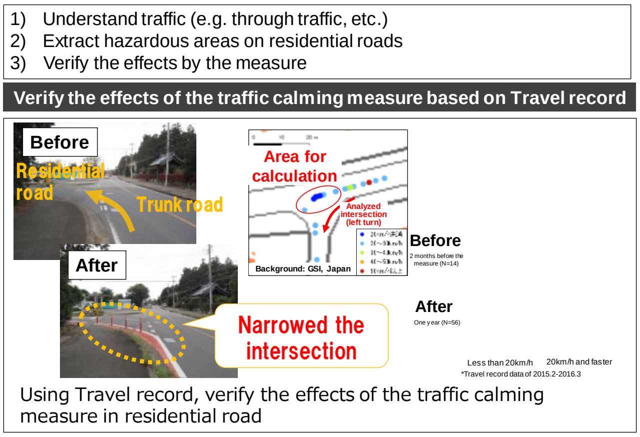


Figure 2. Example of utilization of probe data for improving road safety

Electronic Toll Collection (ETC) in China

6. Electronic Toll Collection (ETC) in China

Keywords	**Electronic Toll Collection, manual toll collection, two-piece e-tag and dual-interface CPU card , Combined ETC system solution, Operating system , national networking, fusion with mobile phone payment**
Authors	**LI Bin, LIU Hongwei, Research Institute of Highway, MOT, China**
Reviewer	**UEDA Satoshi, MCGILL Galen, EHRLICH Jacques, YOSHIDA Hidenori**
Translator	**GUO Yanmei, Research Institute of Highway, MOT, China**
Date	**JUNE, 2018**

1. Description

In 1984, the central government of China issued a policy of "Loaning for Road Construction and Tolling for Repaying", which provided great financial support for expressway construction and drove the fast development of expressway in China for more than 30 years. There are both public fund and private fund into the construction and operation of expressway. In order to pay back the fund and interests of investors, a tolling system had been set up based on the vehicle type and travel mileage in the fully-enclosed expressway network.

At the beginning, operators adopted manual toll collection (MTC) technology. All vehicles were asked to get a paper magnetic ticket or an IC card at the entrance and return it and pay the fee at exit, thus two times stop were required at least. With the rapid development of economy, the traffic flow increases greatly and the expressway becomes more and more congested especially at toll stations, where lots of vehicles wait in a long queue to get the ticket or IC card and pay the fee. However, as the costs of land, construction and staff salaries gradually increase, the original method to alleviate the congestion at toll station by constructing more tolling lanes has become more and more difficult. Therefore, since mid-1990s the electronic toll collection (ETC) technology had been researched, and the ETC technical structure of "two-piece e-tag and dual-interface CPU card" was innovated and established based on 5.8GHz dedicated short range communication (DSRC) technology. From 2007, Ministry of Transport (MOT) begin to deploy the ETC technology nationwide, up to May of 2018, ETC system has covered 29 provinces in China, with 65.5 million ETC users.

ETC is an effective technology to reduce operating costs, improve travel efficiency, and reduce emissions. In this point, ETC is a low cost ITS solution compared with MTC which requires much more land, labour and construction cost.

2. Objectives

Under the current expressway tolling policy in China, how to improve the efficiency of toll stations while keeping the costs as low as possible is an urgent issue for the expressway stakeholder and operators. Therefore the ETC system firstly should realize quick tolling, greatly increase vehicle speed and reduce waiting time at the toll station. And at the same time it should reduce the costs including the land, construction and human resources. On the other hand, China is a developing country with unbalanced development level of different regions, therefore the ETC technology should meet the different demand of different regions and phases. It must ensure long-term coexistence with MTC systems.

3. Technical challenges

The R&D of ETC technology started since mid-1990s in China. After around 10 years of research and test, the ETC technical structure of "two-piece e-tag and dual-interface CPU card" (Figure 1) had been innovated and established, which based on DSRC technology. The main technical challenges are as follows:

- Compatibility with MTC

Considering the unbalanced regional economic development in China, ETC system should adapt to automatic and manual tolling scenario simultaneously. This will lead to long-term coexistence of ETC with MTC system. The "two-piece e-tag and dual-interface CPU card" combined solution is applicative to both non-stop and stop tolling scenario. Vehicles can pass through the ETC lanes smoothly, and also can swipe the IC card finishing non-cash payment in the MTC lanes. This makes it flexible for the expressway stakeholders and operators to decide the construction time and scale, reduce operating risks.

- Supporting offline transaction

Because of the limited communication conditions in some areas, it requires the ETC system to have the offline transaction capabilities. When the communication network is not available or in service, ETC transactions can still be carried out normally. Therefore, it needs good applicability at bad communication network service area.

- Security mechanism

A reliable security mechanism is applied to defend ETC system from invasion and counterfeit. On Board Unit (OBU) adopts Embedded Secure Access Module (ESAM) whose security level is the same as that of the CPU user card. For the CPU user card security, one key for one card, and one key for each transaction. To ensure the authenticity and non-repudiation, each transaction generates an authentication code (TAC). And the identity of the antenna and the e-tags are authenticated to prevent forgery and malicious operation by the illegal antenna.

4. Non-technical challenges

- Apart from the technical challenges, there are non-technical challenges affecting the stable operation and rapid deployment of the ETC system.

- The operating system including process and model

The ETC operating system is shown in Figure 2, and is mainly composed of Clearing and Settlement centre, Key Management and Certificate Authentication, ETC User, ETC Issuer, Expressway Operator and Clearing Bank. The business process, transaction rules, clearing model, and settlement process for nationwide ETC system were established correspondingly.

a) ETC Issuer. As the ETC service agency, ETC Issuer provides ETC users with various services, including OBU and IC card application, issuance, installation, recharging, and inquiries.

b) Clearing and Settlement Centre. The National Clearing and Settlement Centre mainly undertakes responsibility of daily clearing, settlement and parameter management of cross-province ETC transactions, and the coordination, handling issues, dispute transactions, complaints and other issues arising from cross-province operations and services. The provincial clearing and settlement centre undertakes the collection, verification, statistics, and clearing of ETC data, cooperates with the national centre to complete the cross-province toll clearance settlement, and entrusts the bank to complete the clearing and accounting.

c) Expressway Operator. They are responsible for providing ETC services in the road sections, uploading the toll data completely to the provincial clearing and settlement centre, and obtaining the income from clearing bank.

d) Key Management and Certificate Authentication. It provides the related parties with service of key distribution and security authentication to ensure the integrity, consistency and validity of transaction data.

e) Clearing Bank. It receives the transfer instructions from the clearing and settlement centre to realize money transfer across provinces.

- Improving service level though market competition

In the early stage of ETC system development, the government especially the provincial government played a very important role by administrative means. However, with the number of users is become larger and larger, a higher level and cross-province equal service must be provided for the users. Therefore free market competition must be introduced and encouraged, and the administrative intervention and provincial barriers must be reduced greatly at the same time.

5. Evaluation

Up to May of 2018, the number of ETC users in China has reached 65.5 million and the ETC usage rate has reached 38%. ETC system have shown significant effect on solving congestion, improving traffic efficiency, promoting energy conservation, reducing emission, saving land and operating costs. In this point, ETC is a low cost ITS solution compared with MTC which requires much more land, labour and construction cost.

- Significantly reducing the cost

Before applying ETC, constructing new toll lane was the only way to relieve congestion at toll station. In some province one toll station could have almost 40 lanes which occupy a lot of land and human resource. After applying ETC, according to the statistics the capacity of one ETC lane is equivalent to 5 MTC lanes. Therefore, ETC can reduce the number of toll lanes obviously and save a large costs of land, labour and construction. For instance, a toll station which plan to build 40 MTC lanes requires only 8 ETC lanes to achieve the equivalent capacity. It can be calculated that saving 64 hectares of land worth at least 400,000 Yuan, reducing 110 toll collectors with salary of 6.38 million Yuan per year, and saving construction cost by about 96 million Yuan.

- Dramatically reducing congestion

The average time for the vehicle to pass through ETC lane was reduced from 14 seconds to 3 seconds. The capacity and efficiency of toll stations have been dramatically improved, effectively alleviating peak traffic congestion. In some big toll stations, the proportion of ETC transactions during peak hours has exceeded 50%, and greatly relieve congestion of toll station. Comparison of ETC lane and MTC lane is shown in Figure 3.

- Saving energy and reducing emission

Another benefit of ETC system to road user and society is the reduction of energy consumption and emissions. It is estimated that within 12 months of 2017, 111,900 tons of fuel were saved. At the same time, 34,400 tons of pollutant emissions were reduced.

6. Future

For the near future, the following actions will be considered and performed.

- In order to provide users with more convenient and efficient service experience, ETC will be widely used in parking lots, gas stations and other service areas, and integrate with new technologies such as mobile internet, big data, and cloud computing. The third-party mobile payment service provider such as WeChat, Alipay and UnionPay "Quick Pass" have already been used at expressway toll station in some provinces, as a complement to the existing tolling system despite it cannot realize non-stop payment like ETC. With the gradual improvement of social credit environment, the "no card" ETC can be introduced, and evolving to the multi-lane free-flow technology without toll station in the end.

- The ETC technology has good flexibility and expansibility not only for quick tolling, but also for accurately obtaining the real-time traffic flow information, and reduce investment in facilities for road information collection. The DSRC technology is also one of the core technologies of Cooperative Vehicle Infrastructure System (CVIS). With the application of CVIS and the popularity of Roadside Unit (RSU), the existing ETC users will easily upgrade to enjoy the CVIS service, such as safety driving assistance, travel information service, navigation and so on.

- The Chinese ETC technology and mobile payment service, have valuable reference to other developing countries. It can be flexibly adapted to the stop and non-stop tolling scenario, and supports off-line transactions so as to have a low requirement to the communication network. Its non-stop mode can be adopted directly in developed regions with good economic conditions. Stop mode with IC card and non-cash payment can be adopted first in developing regions with poor economic conditions. Therefore, this technology is suitable for the developing countries with unbalanced development regions. In addition, this technology is open and compatible with bank cards, thus making it easier to fusion with the bank and mobile phone payment.

Further information:

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JUNE, 2018

Visual Content

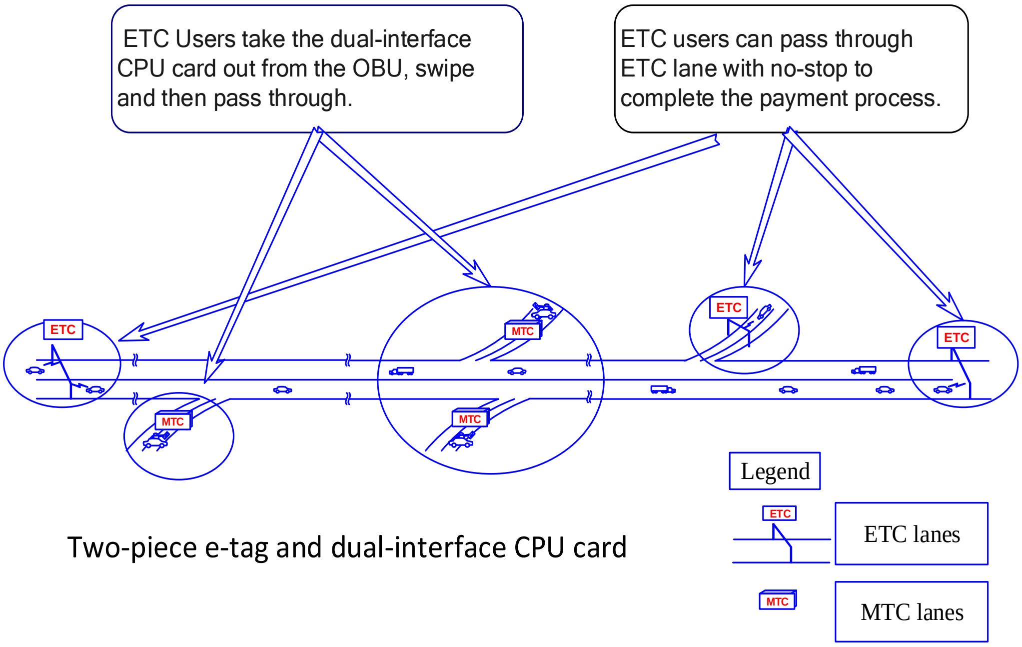

Figure 1 Combined ETC system solution

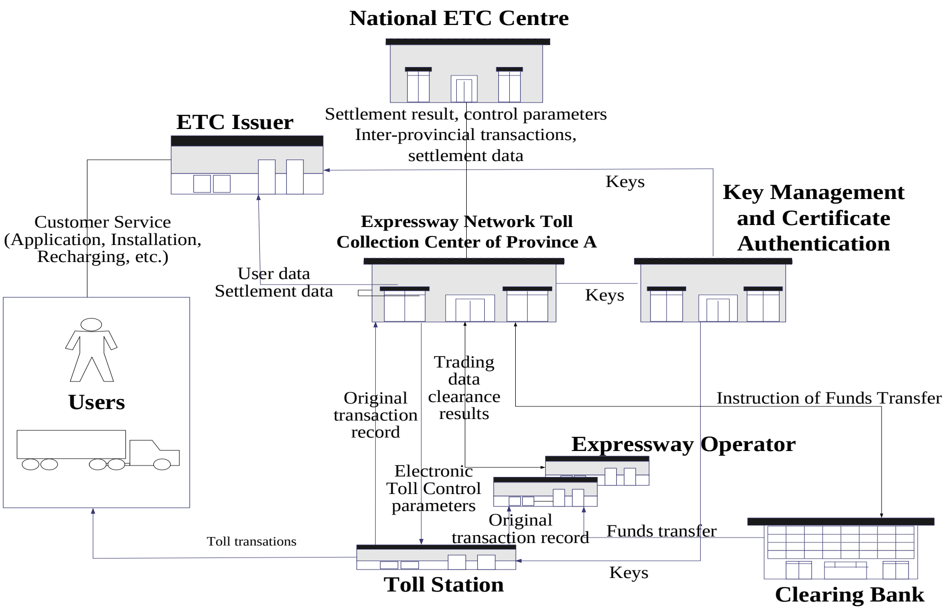

Figure 2 Operating system of ETC

Figure 3 Comparison of ETC lane (left) and MTC lane (right)

Low Cost ITS (Iran)

7. Travel time estimation with Bluetooth technology

Keywords	**Travel time estimation, Bluetooth, Wi-Fi, Licence plate number, Speed camera**
Authors	**Hamid Torfehnejad, Faramarz Maddah, Mojgan Jalilian**
Reviewer	**Daniel Russomanno, Jacques Ehrlich**
Translator	**N/A**
Date	**June 2018**

1. Description

The National Roads Management Centre was established in December 2008 with the aim of optimizing the utilization of roads in the country and minimizing delays in road traffic and improving road safety. Among the practical and required information of road users, it is necessary to be aware of the time it takes to travel to the destination. Therefore, in 2014, the Centre for Management of Iran's Roads defined a comprehensive system of calculating, analysing and informing travel time.

Travel time system is a system in which the average time of the route from point A to B is measured and calculated online. To measure travel time, unique identifiers of the car in the origin (point A) are identified and sent to the server with a time stamp. In the destination (point B), the same identifier is identified, and a sticker is given. The server measures the travel time from the difference in time tags. By identifying a sufficient number of vehicles, the average travel time is calculated using advanced statistical methods. To distinguish cars, different identifiers such as license plates, unique addresses are used to detect Bluetooth devices inside the car or toll tags and so on. Using this system in the city or on the road, it is possible to calculate travel time in each arc and inform the passengers in order to avoid unnecessary trips in the event of a busy route. The use of the travel time system and its notification significantly reduces the actual scrolling time in the route and the maximum travel time.

In March 2015, the Bluetooth travel time system was set up by the Iran Roads Management Centre on several roads and the travel time via the 141 system was communicated to the users. For this purpose, more than 50 Bluetooth devices were installed on the road surface. Currently, this system covers an important part of the arterial routes of the provinces of Tehran, Qom, Alborz, Markazi, Isfahan, Mazandaran, Lorestan, North and South Khorasan, Golestan and Semnan, and operates in the following systems:

Information of Travel time are access able via telephone 141, Rah141 telegram, and the website of the Road Administration Center at www.141.ir. Also, travel time information is displayed to traffic users using traffic signs and variable message signs (VMS).

- Operating routes:

Tehran-Karaj, Tehran-Qom, Tehran-Saveh, Karaj-Qazvin, Qazvin-Rasht, Isfahan-Qom, Qom-Garmsar, Tabriz-Zanjan, Qazvin-Zanjan; Main Roads of Karaj-Chalus, Tehran-Ghaemshahr, (Firouzkooh), Tehran-Amol(Haraz), Tehran-Semnan, Torbat-Heidarieh-Mashhad, Semnan-Mashhad, Mashhad- Bojnourd, Bojnourd-Gorgan, Isfahan-Delijan, Urmia -Mayabad and Arak-Khorramabad.

In the following, a variety of methods for calculating travel time will be provided.

2. Objectives

- Calculate travel time using Bluetooth or Wi-Fi equipment

In this system, the identification of displacements via the Bluetooth system of mobile phones, audio broadcasting of cars, etc. is carried out. Using Bluetooth-detecting devices installed on the road surface, valuable information has been obtained about the speed of travel and travel time that has been made available to the public and used for informational purposes. In these systems, by identifying the macros of clear Bluetooth devices and identifying those devices in other situations, an acceptable statistical sample of the state of motion of vehicles at the surface of the road is obtained. The Bluetooth travel time system is a new system for finding information on road conditions and informing drivers that has been welcomed since 2008 in the global community. In Iran, the Bluetooth travel time system has been running since 2014 and its facilities and limitations have been tested. In each of the roads, information is a registered approach, where the name of the first place is considered as the origin and second place as the destination. For example, the route of Tehran - Nazarabad refers to the orientation approach with the source of Tehran and the destination of the Nazarabad. The travel time computed in a major route is the total travel time of the smaller sections of the route.

Similar to Bluetooth, various devices, Wi-Fi specification, network connectivity, and any Wi-Fi-enabled equipment, provided that it is turned on, can be read and analysed on the same system.

- Calculate travel time using user positioning system

Another example of using this technology is the use of Wi-Fi systems and mobile phone location switches. Identifying Wi-Fi mobile devices on the road surface by identifying each device and identifying devices installed similar to the Bluetooth identification system in different positions on the road surface. Also, a more refined sample technology can also be used to determine the status of traffic on roads using cellular data. The process of using mobile data and location of the phone, along with identification through the positioning systems in the installed applications, including the application 141 used in mobile phones and the position determined by mobile operators, also expanded and in The Development Plan for Iran's Roads Management Centre is located.

- Calculating travel time using the speed controller cameras

The estimated travel time is one of the important applications of the speed control intelligent traffic control system. The vehicle license plate recognition system can be used to estimate the travel time for all vehicle plates, including authorized and unauthorized speeds. In this solution, the license plate detection system will be installed at different points on the road (at the origin and destination) and then calculates the trip time for each car. By analysing the statistics, this time for all cars can be measured with optimum accuracy, moderate and variation at different times of day and week on the road, and made available to the public for decision. Automatic license plate number detection is a system for reading a vehicle license plate using an optical character reader. The license plate number is one of the most relevant information items for automobile authentication, and it is clear from other detecting methods such as Bluetooth, which has more coverage. Auto detection of the license plate number is a fully automated system that extracts the license plate number by using image processing of vehicles passing through a location. To use this system, there is no need to install and equip cars by any other means, such as GPS or radio tags (RFID Tag). The system uses a special camera to take an image of the car passing through and send it to the computer for processing by the license plate recognition software.

- Policy and project development

One of the most important travel characteristics and information needed to manage travel demand information is travel time. Travel times may vary with changing travel conditions, and reduction of navigation time has always been one of the goals of the road management centers. The purpose of this project is to determine and analyze the travel time of the road users and to inform it in selected areas around the country by exploiting the information extracted from the systems for controlling speed cameras and Bluetooth-Wi-Fi devices, anticipating and providing the appropriate response at the time. It is suitable for managing demand and traffic flow. On the other hand, travel time data and analysis based on it play an important role in the management and evaluation of traffic actions. Therefore, the ultimate goals of the Center for Management of Roads of the Country from the definition of this project are the development and full coverage of the country's arterial pathways by estimating the travel time using the following three methods:

- Using the information of the licence plate system of the speed control project in the arterial and the main routes network.
- Analysis of Bluetooth-based or Wi-Fi sensors installed on the road surface; these sensors are used to complete the network in places where speed control systems are not installed or used to complete their coverage.
- Continuous car tracking through GPS or identification and retrieval through GPS and positioning apps.

Therefore, a sensor basket will be used to cover the layout of the grid.

The development phase of the travel time system includes the following:

- Improve the calculation of travel time using other computational algorithms such as variance, average, and ...
- Calculate the travel time of the route using the mobile application locator system
- Development of travel time calculation using licence plate reader system information and through the development of installation of speed control cameras on road of the country.

Use all the travel time taken by all technologies to improve the online traffic situation on the website http://141.ir and the app 141.

3. Technical challenges

One of the most important technical challenges of running a travel time project is how to achieve a higher accuracy in calculating travel time under complex and difficult traffic conditions in different time periods. Also, considering the need to find a pair of vehicles in Bluetooth technology in order to calculate the travel time, a problem is the small number of active devices in a number of roads. In order to overcome this problem, utilize the potential of other existing technologies such as Wi-Fi and positioning and the licence plate system is in operation.

4. Non-technical challenges

On the other hand, obtaining the necessary permissions from the relevant authorities in order to collect the required data regarding the sensitivity of the privacy and personal information of individuals, including non-technical challenges and legal barriers to the project. Also, the weakness of telecommunication infrastructures on the road is another technical challenge facing the project in order to transfer information online from sites to data analysis centers.

5. Evaluation

The acceptable penetration coefficient in Bluetooth technology, Wi-Fi, and licence plate system cannot be clearly stated, but it has generally been shown that if you can find pair of Bluetooth equal to 3 to 10% of the travel over the route, then the accuracy of the estimated travel time to a large extent, it is acceptable. In the projects of the Iran Roads Management Center, according to the calculations and observation by floating vehicle, comparing the number of Bluetooth pairs found with real-route traffic data from traffic systems, the penetration coefficient for the Tehran-Qom freeway road, the Karaj-Chalus route and Tehran-Saveh freeway has been measured (on average) 11, 8 and 10% respectively.

Calculating and estimating travel time between a origin and destination will help road users, especially drivers, make the right decisions about the time and how to start or continue their journey. According to researches, the announcement of travel time to drivers reduces the average travel time. Since 2008, the travel time system has been welcomed with Bluetooth technology because it is low cost and easy to install. This system calculates the travel time in each track by detecting a Bluetooth enabled device in the vehicles at the beginning and end of the track. It is also possible to use other existing technologies such as Wi-Fi, application locators and speed dial cameras to design and develop a comprehensive travel time system project.

Travel time in addition to the various information systems 141 (telephone, website, app, robot and telegram channel, etc.) is also informed via traffic signs and variable message sign(VMS) boards, leading to decision making. It is more appropriate for road users and a shorter travel time average for the entire transportation network. This information is also used by the Road Management Center to analyse demand management conditions and operational actions in network management.

Further information

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Low Cost ITS (Japan)

8. Providing Traffic Information through Public-Private Partnership

Keywords	Traffic information provision, Public private partnership
Authors	Hidenori YOSHIDA, Azusa GOTO
Reviewer	B. Jelisejevs, J. Ehrlich
Translator	N/A
Date	21/6/2018

1. Description

A Japanese company that develops and deploys traffic information collection and dissemination systems and an electronic road information board manufacturer established a Specific Purpose Company (SPC) for providing traffic information within the Public-Private Partnership (PPP) framework by having a concession contract regarding the operation of an ITS facility with the local administrative body (Figure 1).

In this framework, road administrators can provide road users with information about road works, congestion, etc. on Variable Message Signs (VMS). Based on traffic data in urban areas collected by cameras and image processing technology, real-time congestion conditions are analysed and disseminated to the VMS boards. To keep operational costs low, the operator has some sponsors display their advertisements on half of the VMS board and use the revenue collected through the display of such advertisements for the operation and maintenance of the ITS solution. The sponsors utilize this opportunity not only for advertising themselves but also for public service announcements such as traffic safety promotion messages, as part of their Corporate Social Responsibility (CSR) activities.

2. Objectives

In recent years, emerging countries are facing severe traffic problems as their infrastructure is still not sufficiently developed to serve the increasing demand of passenger and goods transport that is associated with their rapid economic growth. Particularly in India, these negative impacts are getting bigger and bigger, such as delay in goods transport caused by traffic congestions, and air pollution due to emissions.

Formerly in India, there was no means to provide traffic information on urban roads, road users had no choice to avoid congestions due to lack of detour information.

In response to such situations, the importance of obtaining information on traffic conditions based on observed data such as traffic volume and density and providing it tor road users has become critical. Thus, this project aims at introducing information provision systems through a sustainable business model.

3. Technical challenges

The SPC installed 14 cameras for obtaining traffic data and 4 VMS boards by entering into an agreement with the civic authority in the City of Ahmedabad in Gujarat State, and thereafter launched the system in October, 2014.

This system automatically measures traffic volume, traffic density, etc. by image processing technology. This real-time traffic data is collected and aggregated into moving average values every three minutes. Based on these moving average values, an index of road traffic congestion is calculated every minute and displayed on the VMS as real-time traffic information.

With mobile controllers, traffic officers can not only be always informed of current traffic conditions in the city, but also send information to VMS boards about irregular traffic congestion due to traffic accidents, local festivals, etc.. Since October 2017, roadwork information has also been sent from the city office to the VMS boards through these mobile controllers.

In addition, the system also utilizes probe data from GPS-equipped taxis as an input for traffic information. Moreover, there is a plan to input probe data from GPS-equipped smartphones in the future.By fully utilizing these different kinds of data, a control center that analyses the information in real time was deployed through a cloud system thereby enabling a low-cost traffic control center, or “virtual traffic control center” (Figure 2).

At the initial stage from 2013 to 2014, the SPC started the system as a field operational test using JICA (Japan International Cooperation Agency)’s Small and Medium Enterprise (SME) Promotion as a part of Japanese government ODA (Official Development Assistance). However, today this system operates as an independent project without any assistance.

4. Non-technical challenges

In this project, the SPC uses half of all VMS display boards screen space for providing traffic congestion information, and leases another half of the screen space to private companies for their digital signage advertising (Photo 1). Thus, the SPC is able to earn the advertising revenue to cover the costs for installation, operation and maintenance of the necessary facilities. This is a good example of realization of a sustainable business model.

At the beginning of this project, there was a concern that some states in India were not so positive about displaying private advertisement on VMS. However, India decided to obligate the leading companies (with total sales of 10 billion rupees or more, for example) to spend 2% of their profits on Corporate Social Responsibility (CSR) activities in 2014. That encouraged these companies to utilize VMS for public service announcement such as traffic manner promotion (Photo 2). As a result, many states currently show their positive attitudes toward the system, and it is expected that the system will be spread to states other than Gujarat.

In order to avoid driver distraction, advertisement is basically limited to still images or images with a simple motion within one second.

5. Evaluation

According to an interview survey of drivers, more than 70% of them are satisfied with the traffic information system, and more than 80% are willing to use the traffic information. Based on the OD survey, little less than 10% of the subjective road users actually chose alternative routes than congested routes.

Through this project, it became possible to make the first inroads towards understanding the fundamental characteristics of road traffic in India, which used to be difficult in the past.

The project is expanding as a business, as proven by the fact that seven more VMS boards were newly installed in October 2017 without any public financial assistance.

6. Future

- The SPC would like to integrate the “virtual traffic control center” that accumulates not only traffic data obtained from cameras but also probe data from taxis and smartphones with a multi-modal system that collects and utilizes traffic information from people’s smartphones.
- The SPC has been requested to build a similar system by the Municipal Corporation of Ahmedabad, as a new project in the riverfront development plan that is coming up in the city center.

Further information:

Tsutomu TSUBOI. “Introduction of Providing Road Traffic Information in India” (2016)
Exhibition Panels at the Highway Techno Fair (2016)
Ministry of Land, Infrastructure, Transport and Tourism of Japan. Overseas Road PPP Council. Efforts
Zero-Sum ITS Solutions India Pvt. Ltd. Website (http://zero-sum-its.co.in)

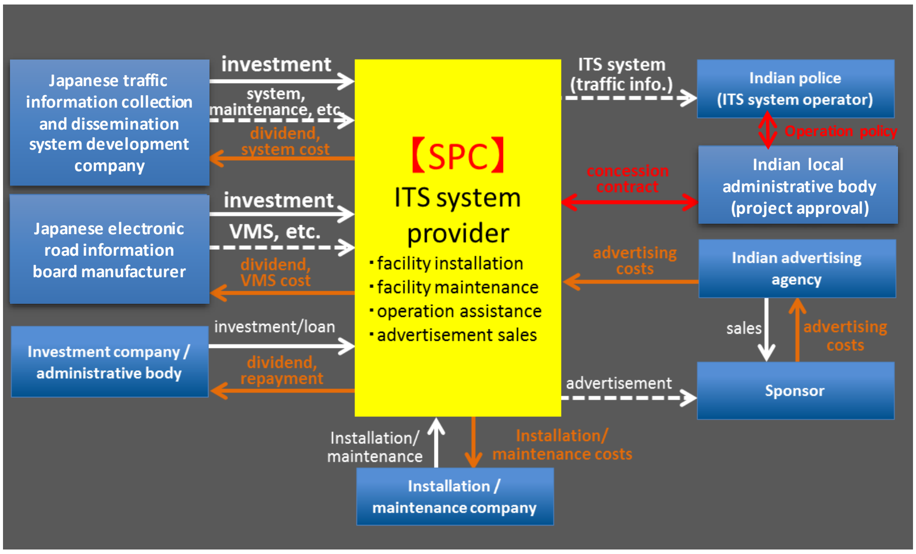


Figure 1. The PPP Business Model

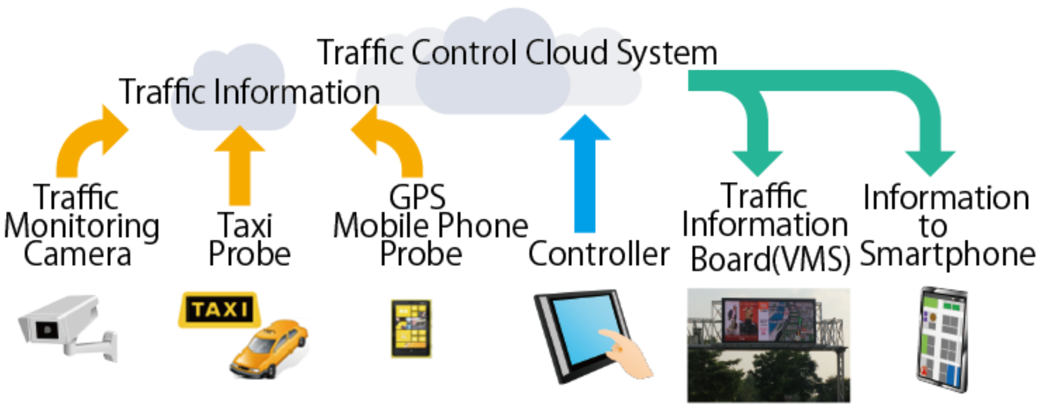


Figure 2. System Configuration

Photo 1. Example of VMS display ©2018 Zero-Sum ITS Solutions India Pvt. Ltd.

Photo 2. Example of VMS used for traffic manner promotion as one of the CSR activities of a private company ©2018 Zero-Sum ITS Solutions India Pvt. Ltd.

Low Cost ITS (Japan)

9. Freight/Public transport management by giving added value to existing systems/frameworks

Keywords	**Traffic management, Digital tachograph, Utilization of the existing system**
Authors	**Hidenori YOSHIDA, Azusa GOTO**
Reviewer	**Boris Jelisejevs, Jacques Ehrlich**
Translator	**N/A**
Date	**25/6/2018**

1. Description

In order to realize ITS services at low cost, it is important for road administrators and/or service operators to fully utilize the existing system and/or framework (e.g., infrastructure, regulation, communication network) by giving additional functions to them, rather than to develop everything from scratch.

This document introduces three examples of the traffic management services for freight and public transport which could be done at low cost according to the level of existing system and framework. That is *(a) the freight fleet management in Japan*, which utilizes ETC2.0 probe information, *(b) the freight fleet management in Thailand*, which utilizes mandatory GPS device for freight vehicles, *(c) the traffic management system in Laos*, which utilizes Wi-Fi packet and smartphones. *(a)* is an example for the country/area where existing system and framework have already been relatively advanced. On the other hand, *(c)* is an example for the country/area where existing system and framework are very limited. As shown by these examples, the services that can be added are different depending on the existing systems and frameworks. Therefore, it is important to consider how to take full advantage of the existing systems and frameworks based on their development levels.

Table 1. List of Cases

Example	(a) Freight fleet management support service with ETC2.0 in Japan	(b) Freight fleet management service with mandatory GPS device in Thailand	(c) Traffic management system with Wi-Fi-packet and smartphones in Laos
Existing system and/or framework	ETC2.0 system (probe data collection system deployed nationwide by road administrators)	Mandatory GPS-equipped On-board Unit (OBU) of buses and trucks	Personal smartphones (widely used)
Additional function, etc.	Providing probe data to private companies for free	Integrating GPS information with Real-time telematics and digital tachograph	Processing smartphone location data and Wi-Fi packet sensor
New services	・Freight fleet management ・Safe driving guidance	・Safe driving consulting service	・Bus location system, urban traffic observation system

2. Objectives

(a) Freight fleet management support service with ETC2.0

Logistics in Japan faces some problems, for example, about a half of delivery trucks need to wait for the arrival of the goods to be loaded for more than an hour. To solve this problem, Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is providing the service to assist logistics companies in improving efficiency of freight fleet management and ensuring drivers' safety, by using probe data of freight vehicles obtained with the existing "ETC2.0 system". Utilization of the ETC2.0 system, which has been already deployed nationwide (see case study (6)), can realize the service at lower cost compared with the case that systems are newly developed.

The service had been tested under the field operational tests since FY 2015, and will be put into full-scale operation in FY 2018.

(b) Freight fleet management services with real-time telematics and digital tachograph

In Thailand, increasing number of traffic accidents has become a serious social problem. Unsafe driving behaviour such as frequent acceleration and deceleration is a problem also from the viewpoint of cargo damages and inefficient fuel consumption. Therefore, to improve traffic safety, bus and truck operators mandatorily equip with GPS tracking system in their vehicles for the enforcement of speed limits and the maximum hours of continuous driving. However, the collected data is not sufficiently utilized for truck management and safe driving guidance in logistics companies.

On the other hand, demands of freight transport are increasing, and there is a strong need to improve a quality of freight transport through a comprehensive management, including the measurement and control of cargo damages and in-transit temperature, antitheft equipment, etc..

For that reason, a Japanese automotive component maker developed a system for safe driving consulting service as well as quality control service of freight transport, based on sequential position information obtained by adding the functions of telematics for real-time communications and digital tachograph for controlling safety driving and fuel consumption to mandatory OBUs with GPS (Figure 2). Freight operators can select the functions to be added to the basic OBU, according to their Willingness-to-Pay for every services.

(c)Low-cost urban traffic observation system with Wi-Fi-packet sensor

In Vientiane City, the capital of Laos, with progress of urbanization and rapid increase of automobile traffic, promotion of public transportation has become an urgent task. However, buses, a main public transportation mode in the city, are not convenient for people because of several problems. One of the problems is that regular buses are not reliable in terms of punctuality, due to frequent traffic congestions and drivers' decision-dependent operation. Another big problem is that no information on bus operations is provided for users.

The objective is to get a real-time information about bus locations as well as traffic conditions and to provide it for users, under very limited infrastructure and communication systems in Laos. For that, a Japanese consulting company developed a bus location system and an urban traffic observation system utilizing data from smartphones, which have been widely spread in Laos.

3. Technical challenges

(a) Freight fleet management support service with ETC2.0

Two types of probe data have been processed in the ETC2.0 system:

- the data mainly for general road management, in which individual vehicle's IDs are automatically changed every day considering privacy protection.
- the data mainly for monitoring heavy vehicles' driving routes, in which each registered vehicle can be identified by the unique OBU-ID according to the registration from logistics operators, etc..

The subject service provides logistics companies with the latter type of probe data of only their own freight vehicles. Since the data collection system (ETC2.0 system) has already been available, only the system which can provide the collected data to logistics companies was necessary to be developed. Therefore the additional cost for this service was not so high.

By using this service, the freight operators are able to see positions of their trucks with ETC2.0 OBU in real time, thus estimate their arrival time more accurately. Based on this estimated arrival time, the operators can arrange the cargo handling staff, thus they can shorten waiting time of them. (Figure 1)

Because ETC2.0 system can record information of not only vehicles' positions but also their risky behaviours such as sudden braking and/or steering, logistics companies are able to identify hazardous locations with higher crash risks. Based on these data, they are able to review traveling routes of their trucks as well as to give safe driving guidance for their drivers.

(b) Freight fleet management services with real-time telematics and digital tachograph

Regarding the safe driving consulting service, the system has a voice guidance function that gives warning when drivers exceed speed limits, make sudden acceleration or deceleration, press the accelerator too strongly, or when high rotation of the engine is detected. This function also gives a voice guidance to encourage drivers when they drive in safe and eco-friendly way. Moreover, the system gives reports to freight operators about the analysis and diagnoses of the driving characteristics and what to be improved of individual drivers, based on the obtained driving record.

Regarding the quality control service of freight transport, the system collects and accumulates various information of the cargos (i.e., ID, vibration, temperature, etc.) from RFID tags on cargo pallets connected to the OBU to the administrative server via 3G network. Based on this information, it visualize the real-time conditions of vibrations, temperatures, etc. of the loaded cargos. This make it possible to dramatically improve freight efficiency and transport quality.

(c)Low-cost urban traffic observation system with Wi-Fi-packet sensor

The bus location system collects real-time locations of buses from smartphones equipped on them. Using this information, the system provide users with not only bus location information of every one second but also traffic congestion information based on driving speeds of the buses (Figure 3). Also, it records times and positions of users who accessed the bus location system by their smartphones, which can be utilized for considering more efficient routes and time schedules.

The urban traffic observation system collects data of general peoples' smartphones using roadside Wi-Fi packet sensors which receive the packets sent by Wi-Fi-equipped devices (i.e. smartphones, etc.). By processing and analysing this data, traffic conditions such as link travel speeds, link travel times and OD traffic volume between intersections are obtained. This information is provided for the public via Internet. Furthermore, it is also shown with large monitor screens installed at bus operation management centres, offices for traffic police and the Ministry of Public Works and Transport, etc. and utilized for their traffic control and management.

These systems can be introduced almost anywhere with easy installation work at low initial cost, as far as the use of smartphones and Wi-Fi is popular.

4. Non-technical challenges

(a) Freight fleet management support service with ETC2.0

Full-scale operation which will be started within FY 2018, data distribution companies chosen by the MLIT from the public will collect fees from logistics companies and run the system. Thus, it will not cost for road administrators to provide this service.

(b) Freight fleet management services with real-time telematics and digital tachograph

It is said that 50% of the expenses of transport industry is fuel cost in Thailand. The system helps saving fuel consumption by improving drivers' driving behaviour. Furthermore, the system prevents frequent fraud by drivers such as fuel theft by monitoring the liquid-level sensors in the fuel tanks.

Furthermore, in this system, by sharing the probe data with other companies, the traffic information becomes more accurate without an additional cost.

(c)Low-cost urban traffic observation system with Wi-Fi-packet sensor

It is possible to cover communication costs for the smartphones equipped on buses and the Wi-Fi packet sensors, by displaying a logo of the mobile phone company which support this systems on the websites where traffic information is provided and on the posters putted in the buses.

5. Evaluation

(a) Freight fleet management support service with ETC2.0

After the field operational tests, the logistics companies which participated in the tests evaluated that this services were useful for shortening waiting time of drivers and cargo handling staff as well as for making quick responses to some situations (e.g., inquiry from cargo owners), by detecting current vehicles positions. Based on these results, MLIT decided to put it into full-scale operation. On the other hand, it was also reported that there was a delay in data collection when trucks were traveling on the roads where road-side units of ETC2.0 system are not placed.

(b) Freight fleet management services with real-time telematics and digital tachograph

Freight companies can cover the costs for introducing and maintaining the OBUs by saving in fuel cost though a promotion of eco-driving and prevention of fuel thefts. One example shows that 17% of fuel consumption in average could be reduced by the promotion of eco-driving with this service.

(c) Low-cost urban traffic observation system with Wi-Fi-packet sensor

According to a questionnaire survey, for example when using buses for business purposes, 49% of the respondents answered "the frequency of bus use has increased" and 37% answered "the waiting time for buses is reduced".

6. Future

(a) Freight fleet management support service with ETC2.0

In order to make the service more convenient, new type of road-side units is under development, which logistics companies can put in their offices at lower cost and obtain probe data more quickly. It is expected that such a development can not only improve the subject service, but also contribute to data-oriented road management, which was the original purpose of the data, by expanding the area where probe data can be collected.

(b) Freight fleet management services with real-time telematics and digital tachograph

The maker plans to provide congestion information by utilizing probe data collected through the GPS-equipped OBUs, and further to develop a vehicle dispatch system that reflects the congestion information. These are expected to contribute to the improvement of freight efficiency.

(c)Low-cost urban traffic observation system with Wi-Fi-packet sensor

It is expected that the information obtained in these systems can be utilized for various applications of road management. For example, damage on road pavements may be detected by observing the sections with extremely lower travel speeds even without traffic congestions; submersion may be detected by observing the sections with lower travel speeds during rain.

Further information:

Ministry of Land, Infrastructure, Transport and Tourism of Japan. "Fleet Operation Management Assistance Service using ETC2.0" (2017)

Ichikawa T. "IoT-Based Efforts for Improving Safety and Transportation Quality in Thailand", IATSS Review, Vol.42, No.2, pp.144-150 (2017)

Smartphone-use Bus Location System in Laos, https://www.youtube.com/watch?v=WuRFJhPsy3c

Ministry of public works and transport : summary report : Lao PDR, verification survey with the private sector for disseminating Japanese technologies for new location information system and traffic observation system for urban transport improvement in Vientiane city, http://open_jicareport.jica.go.jp/pdf/1000028290.pdf

Visual Content

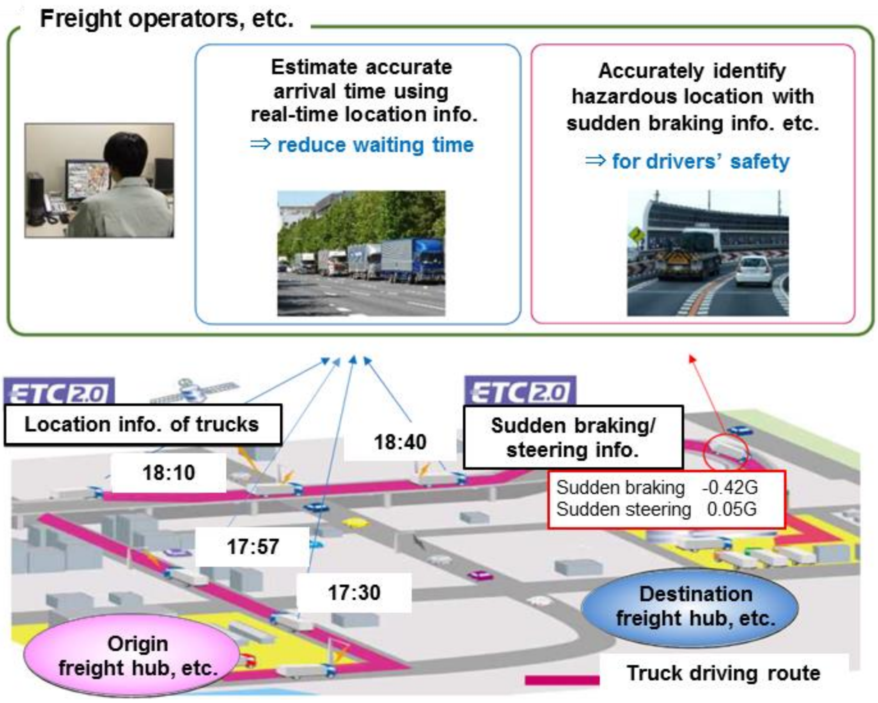


Figure 1. Image of the services and expected effects of the (a) freight fleet management support service with ETC2.0

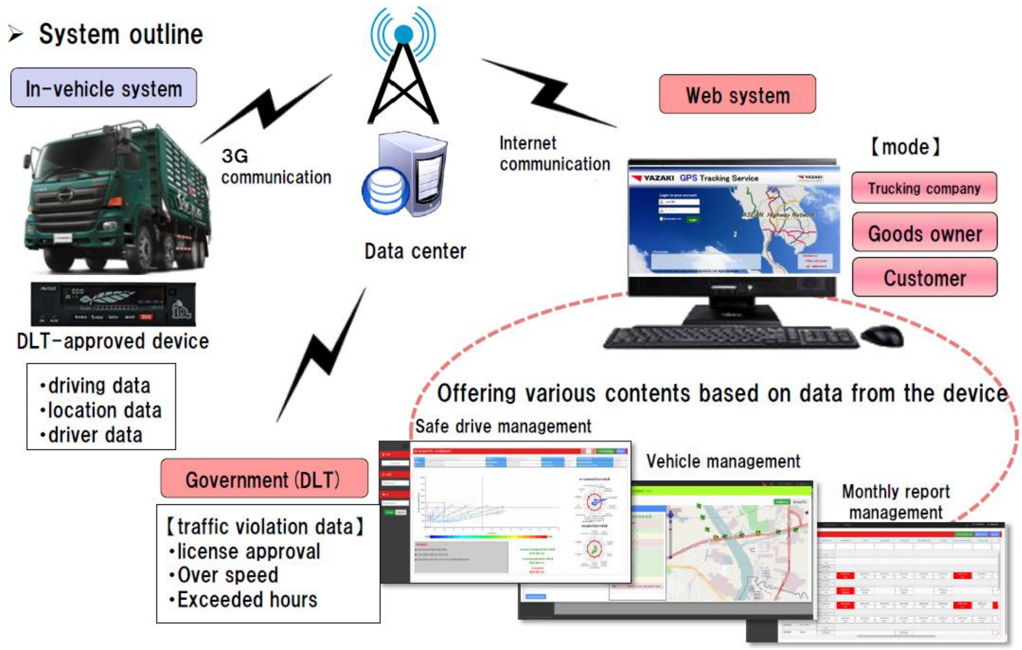


Figure 2. System outline for the (b) freight fleet management services with real-time telematics and digital tachograph

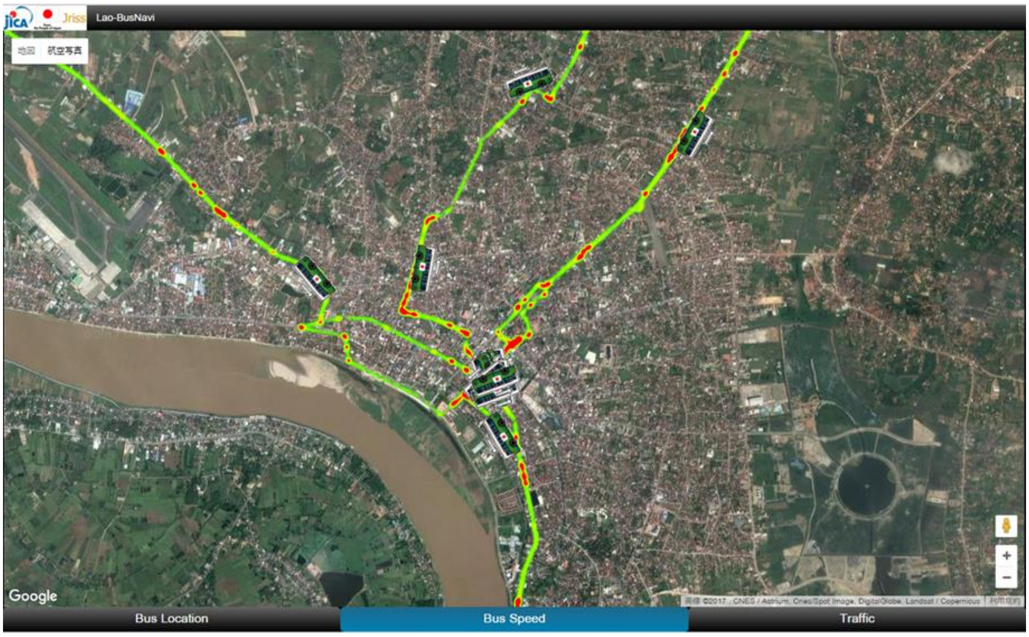


Figure 3. Distribution of Driving Speeds of Buses in the (c) low-cost urban traffic observation system with Wi-Fi-packet sensor

Low Cost ITS (Japan)

10.Principles for Disaster Control in ETC2.0

Keywords	**Natural disaster, probe data collection, probe data utilization**
Authors	**Yuji IKEDA**
Reviewer	**Boris Jelisejevs, Jacques Ehrlich**
Translator	**N/A**
Date	**24/07/2018**

1. Description

"Understanding road traffic condition" in disaster-stricken area using probe data has been recognized as important since the Kumamoto Earthquake in Japan in April 2016. This case study introduces the challenges to utilize probe data for disaster recovery in Japan, and principles for disaster control in ETC2.0 probe system.

2. Objective

"Understanding road traffic condition" in disaster-stricken area using probe data has been recognized as important since the Kumamoto Earthquake in Japan in April 2016.

Figure 1 shows the action timeline for ensuring roads after disasters. In phase 1, immediately after disasters, road administrators work for life-saving and emergency related activities such as inspection of crucial facilities, grasping disaster-stricken conditions, securing routes for emergency vehicles. In phase 2, it is necessary to make roads available for emergency vehicles, transport of necessary goods for rescue/medical aid and transport of necessary heavy machinery and goods for restoration. Then, in Phase 3, roads need to be open for regular road users in order to resume a normal life.

The objective is to develop the system to support such activities for disaster control.

From immediately after the disaster to restoration, it is always necessary to observe "the latest situations of which route is passable (passable route)". With probe data, such information can be obtained in a short period of time (e.g. 1-2 hours) and displayed on a map. Moreover, since information is constantly updated, it is possible to observe changes of road traffic conditions over time. It would be valuable for restoration planning as well. Therefore, "Information Sharing Platform for Road Management (a.k.a. Passable Route Map)" has been developed and is available for the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Regional Development Bureaus, and local road administrators, so that they can share the ETC2.0 probe data after disasters (Figure 2).

This system has been used by MLIT, but it is expected that information of passable routes for emergency vehicles, etc. will be shared among road administrators, fire department, police, etc. in phase 1. Then, it will be further shared with emergency goods suppliers (water, food, clothing, etc.) in phase 2. Moreover, it is also expected that information will be combined with damaged conditions after examinations and opened to the public in phase 3.

3. Technical challenges

As shown in Figure 3, in Japan, ETC2.0 probe data is collected through the following process:

a) **Collection** of probe data from individual vehicles by **Roadside Units** (RSU; called as "ITS spot"),

b) **Transmission** of probe data by **fiber optic communication line**,

c) **Aggregation** of probe data from the roadside units in **the Probe Servers** located in regional development bureaus and expressway companies and relay to the probe integration server, and

d) **Aggregation and Processing** of probe data nationwide by **the Probe Integration Server**.

If any of the above-mentioned equipment in the four steps does not work at the time of disaster such as earthquake, probe data cannot be collected. Thus, it is necessary to take some measures against possible malfunction in the equipment. Table 1 shows a list of the possible measures for ETC2.0 probe system under consideration.

Here, of course the more these measures are taken, the higher the system costs would become. Therefore, it is important to consider a balance between the system resilience and costs, according to local situations and disaster risks.

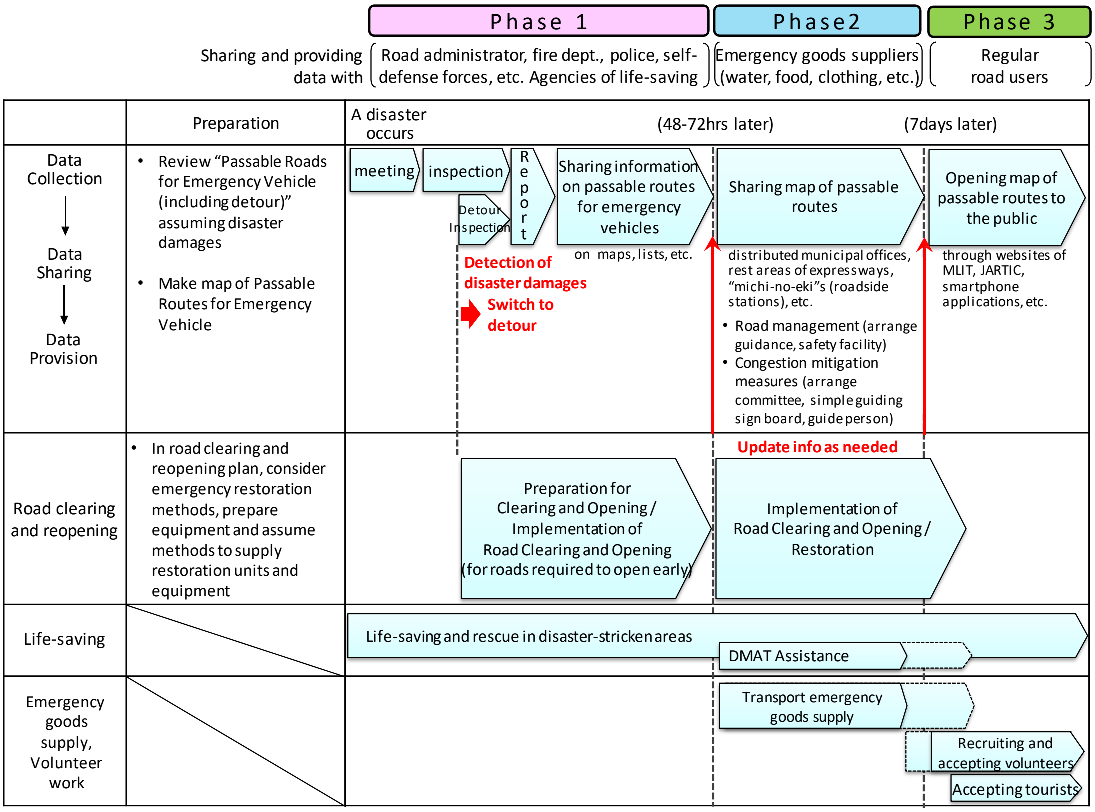
4. Non-technical challenges

In May 2017, "Information Sharing Platform for Road Management" started to combine probe data from ETC2.0 (public sector) and private sectors (passenger cars, taxis, and trucks, as shown in upper left in Figure 2) so that more highly condensed and precise information of passable routes could be obtained. Although merely ETC2.0 data may not be able to capture traffic conditions on roads with low traffic volume especially at night, with private-sector probe data, more accurate traffic information can be obtained promptly.

Further information:

Makino, H., Itubo, S., Toriumi, D. and Mizutani, T. "Feasibility study of identifying passable routes after disasters made from ETC2.0 probe data", Proceedings of 23th ITS World Congress (2016)

Visual Content



*DMAT (Disaster Medical Assistance Team): Specialized medical assistance team which travels to disaster affected area quickly after disaster (e.g. major earthquake) in order to provide emergency medical services and to save lives of disaster victims.

Figure 1. Timeline for ensuring roads after disasters

Source: The 57th Basic Policy Working Group, Panel on Infrastructure Development, MLIT

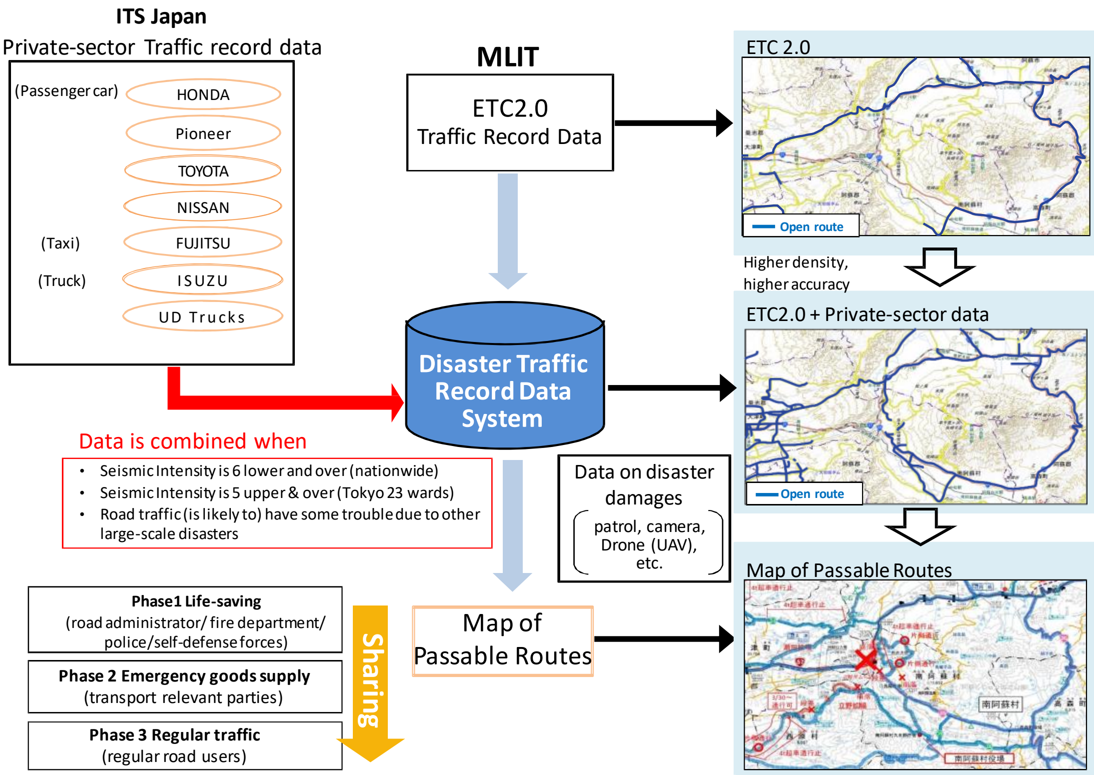


Figure 2. Information Sharing Platform for Road Management (a.k.a. Passable Route Map)

Source: Press Release on May 31, 2017. MLIT

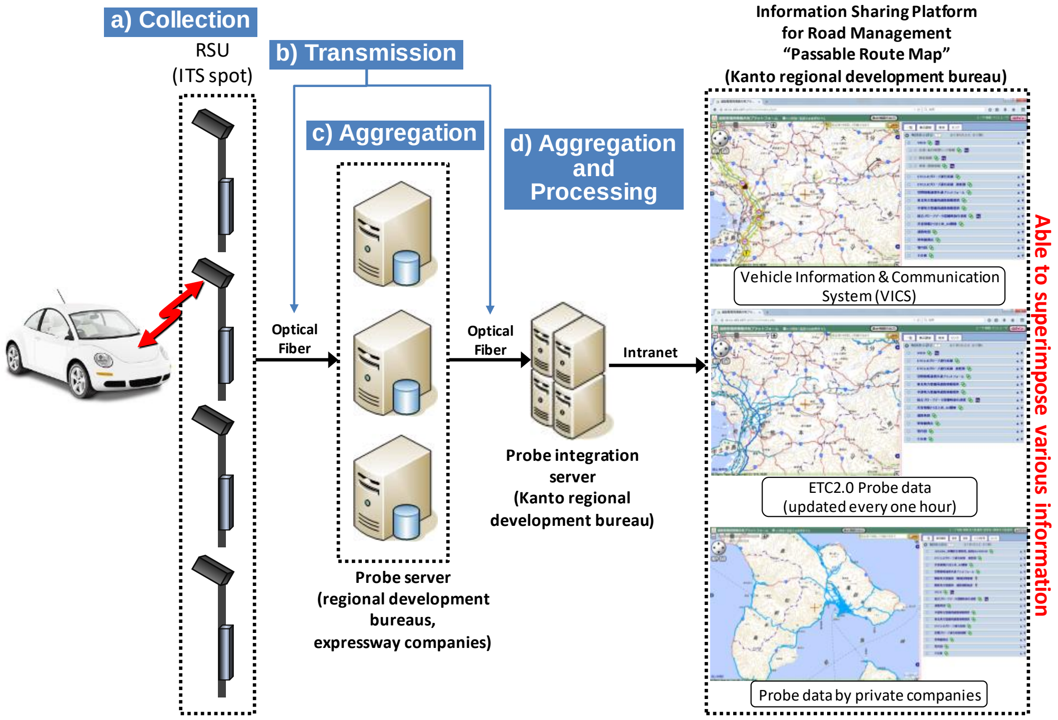


Figure 3. System structure for ETC2.0 probe data

Table 1. Possible measures against equipment failure at the time of disasters

Steps for collecting ETC2.0 probe data	Equipment	Possible malfunction at the time of disaster	Measure content
a) Collection	RSU (ITS spot)	Breakdown by electric outage	**<u>Installation of emergency power supply</u>**
		Breakdown by damages on the equipment	**<u>Substitution with "Portable ITS Spot" (Post-disaster action)</u>** ・ "Portable ITS Spot" is small, lightweight, and easy-to-install RSU for ETC2.0 probe data. ・ Data collection at areas without ordinary ITS Spot is possible.  Photo of "Portable ITS spot" (installed on an existing pole)
b) Transmission	Fiber optic communication line	Failure in transmission due to disconnected communication line	**<u>Duplication of the communication lines</u>** (E.g. apply loop configuration for communication lines, switch to other methods such as wireless communication)
c) Aggregation	Probe server*1	Breakdown due to damages or failure of the equipment by vibration and/or impact	**<u>Installation of seismic isolated equipment</u>**
			<u>Duplication of the server</u> (switch to the backup server*2)
d) Aggregation and Processing	Probe integration server*2	Breakdown due to damages or failure of the equipment by vibration and/or impact	<u>Installation of seismic isolated equipment</u>
			<u>Duplication of the server</u> (switch to the backup server*2)

*1: Assuming measures against electric outage is applied to the buildings where the servers are located.

*2: It is important to install the duplicated equipment in a place that would not be damaged by the same disaster.

Low Cost ITS (Germany)

11. Bluetooth Sensors for Traffic State Estimation and Automatic Incident Detection on Freeways

Keywords	**Bluetooth Detection, Wireless Traffic Detection, Travel Times, Traffic State, Automatic Incident Detection, Freeways, Motorways, Network Control**
Authors	**Martin Margreiter, Chair of Traffic Engineering and Control at Technical University of Munich / MobilityPartners (www.mobility-partners.com)**
Reviewer	**Jacques Ehrlich, Kian-Keong Chin**
Translator	**N/A**
Date	**June 2018**

1. Description

Usage of stationary low-cost Bluetooth Detectors next to the freeway to detect Bluetooth-enabled devices with activated radio interface on board of passing vehicles. After re-identification of the device's MAC-address at another detector location, the travel time of this device – and therefore the carrying vehicle – can be determined between both locations (see figure 1 and figure 2). The approach also aims at using this information for traffic state determination of a whole freeway network targeting at a fast and reliable dynamic net control.

- A detector has a range of several hundred meters (depending on type, location and positioning of the antenna) and can therefore cover multiple lanes in both directions.
- Since 2010, several hundred Bluetooth detectors are being tested and nowadays used for traffic applications in the testbed in Northern Bavaria, Germany.

2. Objectives

- Determination of valid travel times on the freeway using a dynamic and adaptive filter algorithm.
- Fast and reliable determination of the traffic state and incidents (see figure 3) with their spatial and temporal behaviour (start and end time, incident location and length, affected lanes etc.).
- Using this information for a dynamic re-routing in the freeway network.

3. Technical challenges (solved)

- Due to data privacy issues, the MAC addresses of the detected devices have to be shortened, to not allow for the identification and continuous tracking of devices. This leads to potential collisions of the same hash code because several different devices could now share the same ID, which leads to wrong travel time calculations. The development of a reliable filter solved this issue by omitting wrong travel times.
- Wrong travel time determination due to missed individual detections of vehicles, vehicles having a stop between the two relevant detectors or vehicles leaving the freeway for some time

at an off-ramp between the two relevant detectors and returning later. Also here, the filter algorithm solves this problem, by detecting unrealistic travel times.

- Reliability of the automatic incident detection using partly very scattered data with only a share of the overall number of vehicles passing by. The development of a dynamic incident detection algorithm, taking into account the large standard deviation of the speeds on German freeways and the low detection rates in off-peak hours, solved this problem and provides a reliable and fast detection even with less data.
- Multiple active Bluetooth devices on board of one single vehicle might lead to a biased average travel time. This issue was solved by the identification of device pairs over several detector location.
- Mean travel speeds based on Bluetooth in the freeway network of Northern Bavaria, Germany are in average approximately 15 to 20 km/h lower than the real travel speeds. This is due to higher equipment rate amongst trucks with Bluetooth devices. Since trucks have to follow a strict speed limit of 80 km/h in Germany, this higher equipment rate amongst slower vehicles – in comparison to a lower equipment rate amongst faster private cars – leads to a biased (lower) average speed determined from Bluetooth data. However, with the knowledge of the share of trucks, this systematic deviation of the Bluetooth travel speeds can be corrected mathematically to represent the real average travel speeds of all vehicles.

4. Non-technical challenges (solved)

- Mainly also data privacy issues especially in Germany with high privacy standards. This could be solved through technical solutions like shortening and encryption of the MAC address directly on the sensor itself, changing the encryption method every 24 hours, deletion of the individual detection data after travel time determination etc.

5. Evaluation

- Bluetooth detection has proven to be a reliable and cost-efficient (inexpensive sensor and antenna, only one unit needed for the whole cross-section, very low energy consumption and therefore operation possible with only solar power, no maintenance needed, easy and inexpensive installation next to the roadway) source for real-time travel time data including traffic state and incident detection. The incident detection quality (false alarms, reaction time etc.) is slightly better than current methods based on local detection.
- Detection rate (amount of detected Bluetooth devices as a share of whole traffic) is in average between 20 % and 25 % depending a lot on the share of heavy-duty vehicles (higher equipment rate of trucks, around factor 5 in comparison to cars) but also the weekday and time of the day.
- In average, every sixth vehicle has two instead of one active Bluetooth device on board.
- Bluetooth data shows no disadvantage in quality and detection speed of incidents in comparison to traditional methods based on inductive loops or automatic number plate recognition.

6. Future

- Rather stable equipment rate with active Bluetooth devices (Smartphones, hands free devices, Bluetooth interfaces in cars etc.) over the last years in Bavaria, Germany.
- Potential of using also WiFi detectors as a data source in the future.

Further information

Contact: **http://www.vt.bgu.tum.de/en/staff/mitarbeiter/margreiter-martin**

https://mobility-partners.com/en/?team=martin-margreiter_en

Further read (publications on Bluetooth):

https://www.researchgate.net/profile/Martin_Margreiter

Visual Content

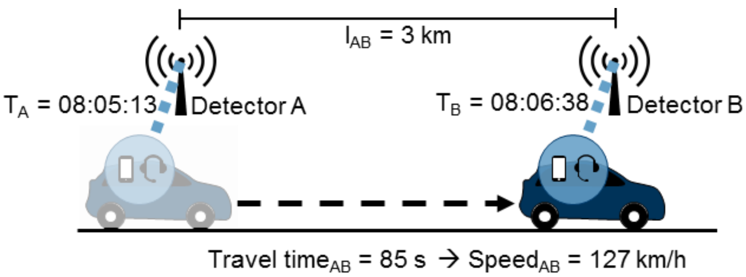


Figure 4: Technical principle of Bluetooth detection

Date	Unix time	BT Mac address	Detector
26.04.2010	1272297470	00:02:60:0D:AA:EB	A
26.04.2010	1272301060	00:05:99:65:40:9A	A
26.04.2010	1272301360	00:07:00:E8:1A:0F	A
26.04.2010	1272301850	00:06:30:D4:BA:95	A
26.04.2010	1272301860	00:08:20:51:B5:6B	A
26.04.2010	1272301910	00:01:10:FC:B0:EA	A
26.04.2010	1272301910	00:03:12:9F:44:C6	A
26.04.2010	1272301930	00:04:01:57:52:E7	A
26.04.2010	1272302010	00:01:10:FC:B0:EA	B
26.04.2010	1272302020	00:02:60:0D:AA:EB	B
26.04.2010	1272302030	00:03:12:9F:44:C6	B
26.04.2010	1272302040	00:04:01:57:52:E7	B
26.04.2010	1272302050	00:05:00:E8:1A:0F	B
26.04.2010	1272302060	00:06:30:D4:BA:95	B
26.04.2010	1272302070	00:07:99:65:40:9A	B
26.04.2010	1272302080	00:08:20:51:B5:6B	B

BT Mac address	Travel time A->B	speed
00:01:10:FC:B0:EA	100 s	180 km/h
00:02:60:0D:AA:EB	4550 s	4 km/h
00:03:12:9F:44:C6	120 s	150 km/h
00:04:01:57:52:E7	110 s	164 km/h
00:05:00:E8:1A:0F	990 s	18 km/h
00:06:30:D4:BA:95	210 s	86 km/h
00:07:99:65:40:9A	710 s	25 km/h
00:08:20:51:B5:6B	220 s	82 km/h

Figure 5: Typical Bluetooth raw dataset and travel time results

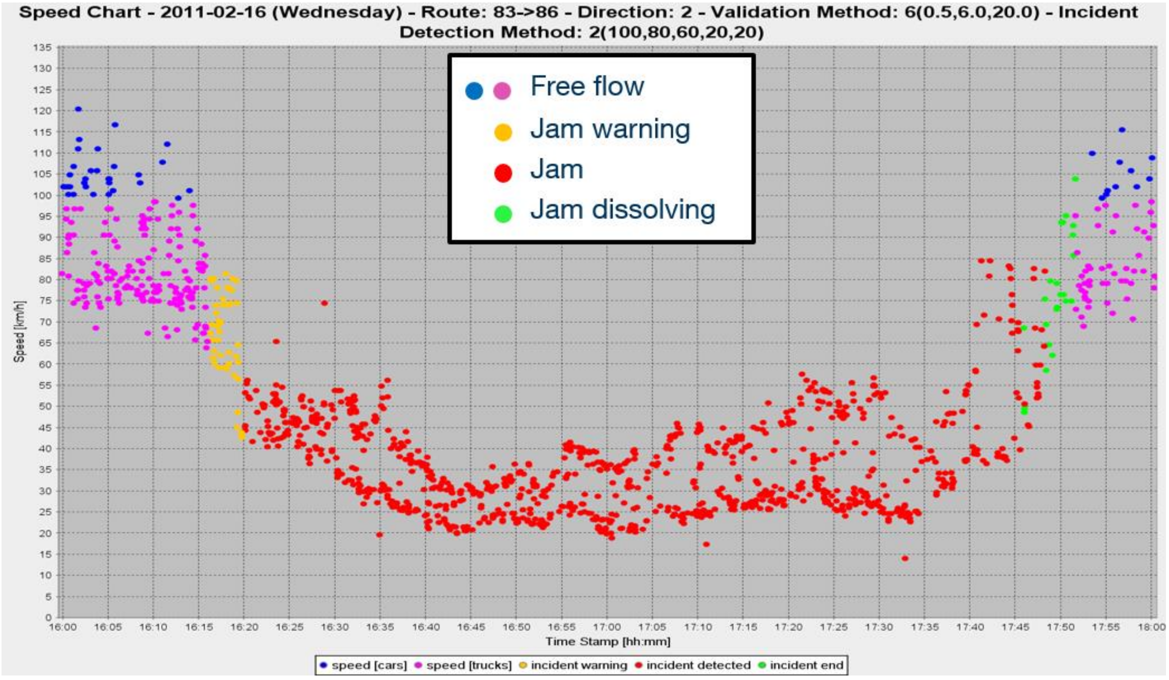


Figure 6: Exemplary visualization of speeds over time derived from Bluetooth data including an incident situation

Low cost ITS (South Korea)

12.Low Cost ATIS of Korea, Traffic Information Service using Navigation Data Thru Private and Public Partnership

Keywords	**Private Probe Navigation Data, Traffic Information Service, National Transport Information Centre, Private Public Partnership**
Authors	**Keechoo Choi, Seong J. Namkoong, Yongju Yi**
Reviewer	**Asuza Goto, Galen McGill, Jacques Ehrlich**
Translator	**Keechoo Choi**
Date	**May 19, 2018**

1. Description

In spite of the continuous but slow deployment of ATIS in Korea, the gap between desired and implemented stages remains large. The national coverage of traffic information only amounts to 20% of the whole network, and this suggests that a much longer time than expected will be required to completely build up travel time network to 100% coverage. In response, the government has changed policy to use more resources combating traffic crashes and accidents while collaborating with the private sector in providing real time traffic information to general public. The private sector companies include navigation companies and cellular phone-based navigation companies.

2. Objectives

The purpose of this case study is to introduce the current method of extracting link travel times using probe vehicles based on a partnership between private and public sectors in Korea and to spread this concept to other countries as a low cost ITS ATIS services. The cases study also includes the evaluation of the quality of both public and private traffic information in such a manner that possible problems in using the combined information can be minimized. Criteria to evaluate the quality are introduced and this paper also tries to suggest a way to improve the current model to improve accuracy, completeness and coverage etc.

3. Service Description

The basic traffic collection mechanism uses probe vehicles equipped with GPS. Previously, a dedicated GPS module or in-vehicle unit was installed. Nowadays, the cellular phone is primarily the source of GPS data. Once you are user of either T-map (provided by SK Telecom) or Kakaomap navigations (provided by Daumkakao), you are also a contributor of traffic information. The navigation apps use the traffic information to find the optimum/cheapest/shortest routes. Both Apple and Android mobile apps are available and about 18,000,000 users are using the service of T-map, which is leading the market service. KakaoNavi, KT navigation, and other navigation services are also available.

While those private companies obtain the data, they also provide the traffic information data to public agencies including the Ministry of Land, Infrastructure and Transportation and more specifically to the National Traffic Information Centre, to be used for the general public. Some Automatic Vehicle Identification (AVI) based traffic information efforts driven by public sector more or less have been discouraged since ‘cheaper’ way of collecting and sharing traffic information is now available. The mobile app and easy dissemination of traffic information also played an important role in making these successes. With this, the government can save money even after providing support through subsidies for the private sectors, and the saved money can be used for expanding traffic safety improvements.

4. Technical aspects and challenges

To use private-generated traffic information for general public uses, some measures should be identified and evaluated to determine whether the public can use private information with confidence. The following indicators were identified and evaluated.

- Accuracy

In the expressway section, the similarity of the private traffic information compared to the public traffic information was examined. In the urban arterial section, the travel time provided to the National Traffic Information Centre by each agency (or company) was compared to actual travel time measured by probe vehicle. For expressway section, certain data were excluded such as when link is a ramp or road section that is less than 500m in length. Urban arterial sections were grouped as continuous standard links with 1km of minimum length, because short standard link length could be affected by traffic signals.

In case of urban arterial, a total of five experimental probe vehicles were injected from August 25, 2015 to September 16, 2015, and the actual travel time was estimated by running the selected routes in each survey area. After acquiring the trajectory data through a smartphone application in each vehicle, the travel time for each standard link was calculated. Travel time data transmitted to the National Traffic Information Centre by each agency (company) was compared with probe data from the same time and segment travelled.

See Figure 1. “Prove vehicle Travel Record (Example)” (at the end of the document)

- Completeness

Completeness is defined as the number of expected traffic variables for a unit of time. In this study, the meaning of completeness was defined as the ratio of the data transferred to the National Traffic Information Centre without any missing data during the collection time period. During the collection time frame there were a total of 168 5-minute time periods (14 hours form 6 am to 8 pm: N=14×60min/5min)). Traffic information from the National Traffic Information Centre, company “A”, and company “B” were compared for September 1, 2015. Since the public traffic information data have a transmission period shorter than 5 minutes, the data was aggregated into 5-minute bins and analysed.

- Coverage

Coverage is defined as the ratio of the standard link for which the speed data available and is transmitted to the National Traffic Information Centre to the total number of standard links. The spatial extent of the coverage analysis may be limited to a specific area, but this study is based on the standard links nationwide. In addition, the coverage criteria can be based on either the number of standard links or the total extension of the standard links. In this study, the total extension of standard links is applied to decide the coverage criteria because the network is composed of a plurality of short standard links which cause distortion of the coverage index in urban arterial. Also, it is judged that the speed data of the link is being transmitted if the degree of completeness is more than 50% among 14 hours from 6 am to 8 pm, same as completeness.

5. Non-technical challenges

There have been very few governments performed studies on the quality evaluation of traffic information linked to the National Traffic Information Centre. There is some research suggesting the method for evaluating the accuracy of vehicle detectors, or quality analysis performed by the private companies themselves.

ITS America's Advanced Traveller Information System (AITS) Committee (2000) defined accuracy, reliability and real-time information as important items for determining data quality. The real-time traffic data is defined as four types of traffic sensor data: accident and event record, video image, road sensor data, and environmental sensor data. Data quality standards for seven attributes for each type of data were presented. Battelle Memorial Institute (2004) presented a methodology for assessing the quality of data when traffic data collectors or users provide, share, and use the data. Guidelines such as definition of traffic data quality, quantitative and qualitative measures of traffic data quality, satisfaction level of traffic data quality, and evaluation method of traffic data quality were suggested.

In this case study, we analysed the accuracy based on the six items presented by Battelle Memorial Institute (2004). We further divided the analysis by road classification into expressway and urban arterial categories. In case of completeness and coverage, the calculation method of indicators is changed to verify the results of quality analysis with the National Traffic Information Centre level.

6. Evaluation

- Accuracy

The similarity between public sector and private sector traffic speed on the expressway varies slightly from day to day, but the average of company “A” is 92.3% and that of company “B” is 90.6%. The number of standard links included in this analysis was 2,254. With 3 days divided into 5-minute increments, a total of 980,000 sample were generated. Traffic speed is estimated by real-time data (in case of company “A”) or pattern data (in case of company “B”). Therefore, traffic speed provided by both companies are slightly different from each other.

Table 1. Accuracy Analysis Result of Expressway Traffic Information

Day	Company “A”			Company “B”		
	1-MAPE	RMSE (sec)	# of Samples	1-MAPE	RMSE (sec)	# of Samples
’15. 9. 1	92.5%	31.5	326,474	90.8%	39.9	326,474
’15. 9. 2	92.1%	32.3	339,377	90.5%	46.7	339,377
’15. 9. 3	92.2%	29.8	317,728	90.5%	38.0	317,728
Total	92.3%	31.2	983,579	90.6%	41.8	983,579

Accuracy of traffic information on urban arterial differed somewhat by region. This is because there are differences in the regional traffic network and congestion level. The average of company “A” is 67 to 72% and that of company “B” is 55 to 70%. In the case of the government data, the accuracy of UTIS (Urban Traffic Information Systems) -based traffic information is 56 to 75% and that of other public information is 58 to 81%. In general, on urban arterials, traffic speed is slow, the length of individual standard links is very short, and the accuracy is slightly lower than that of expressway due to the signal effect.

Table 2. Accuracy (1-MAPE) Analysis Result of Urban Arterial by Region

Area	Company “A”	Company “B”	Public(based UTIS)	Public(etc)
Seoul	72.8%(138)	58.8%(133)	69.7%(83)	81.0%(16)
Gyeonggi	72.3%(240)	69.8%(230)	68.6%(265)	72.4%(81)
Busan	69.2%(88)	63.8%(92)	70.1%(53)	72.4%(33)
Daegu	71.1%(82)	57.6%(85)	75.8%(59)	74.4%(64)
Incheon	67.8%(80)	55.3%(82)	65.5%(84)	67.3%(38)
Gwangju	69.8%(58)	64.6%(50)	60.7%(23)	66.2%(28)
Daegeon	69.9%(90)	70.7%(91)	56.1%(51)	58.4%(102)

* The number in the bracket represents sample size

- Completeness

Company “B” had 97.0% completeness as speed data was received in 163 out of 168 cycles for all standard links. In this research, the completeness index criteria were set as 80% or more cycles should be transmitted data during analysis period, which is converted as 135 or more cycles over 168 overall analysis cycles. 84.7% of the standard links were satisfied the criteria by Company “A”, while UTIS-based public data was 72.9% and other public data was 77.0%. Several links show lower level of completeness because of difference in the server setting of the traffic information collecting and providing entity and an error appearing at the traffic information collecting device unit. For reference, among the approximately 260,000 total standard links, the number of standard links that had speed information transmitted at least once during the analysis time was 87,562 for company “A”, 221,142 for company “B”, 96,078 for UTIS based public and 51,160 for other public.

Table 3. Analysis Result of Traffic Information Completeness

Category	Company "A"	Public (based UTIS)	Public (etc)
Link rate of Completeness index over 80%	84.7%	72.9%	77.0%
Link rate of Completeness index below 80%	15.3%	27.1%	23.0%
Total	100.0%	100.0%	100.0%

* September 1, 2015, 06:00~20:00, Based on National Traffic Information Centre Traffic Speed Data

See Figure 2. "Analysis Result of Traffic Information Completeness" at the end of the document

- Coverage

The proportion of standard links satisfying 50% of completeness (speed data of more than 84 cycles out of 168 cycles are transmitted to Traffic Information Centre) is 31.0% for company "A", 89.6% for company "B", UTIS based public data was 21.7%, and the other public data was 18.8%. Company "B" uses the pattern data to generate speed information for as many standard links as possible and transmits them to the National Traffic Information Centre. If the spatial range of coverage analysis is limited to standard links that occur recurring or non-recurring congestion, rather than the entire standard links, the proportion of standard links that satisfying 50% of completeness is increased except company "B"; 58.1% for company "A", 84.3% for company "B", 69.8% for UTIS based public, and 40.1% for other public sector (See Table 4). The reason for the coverage index increasing is that the agency is mainly focusing the congested standard links to create and process the traffic information.

Table 4. Analysis Result of Traffic Information Coverage

Category	Company "A"	Company "B"	Public (based UTIS)	Public (etc)
Total Link (128,127km)	31.0%	89.6%	21.7%	18.8%
Recurrent or Non-recurrent Congestion Link (9,446km)	58.1%	84.3%	69.8%	40.1%

* September 1, 2015, 06:00~20:00, Based on National Traffic Information Centre Traffic Speed Data

See Figure 3. "Analysis Result of Traffic Information Coverage" at the end of the document

7. Future

Currently, Korea is in a transitional phase preparing to provide C-ITS and automated driving services. Through efficiently utilizing and sharing private traffic information rather than expanding existing information collection infrastructure such as Vehicle Detection System (VDS), Dedicated

Short Range Communications (DSRC), and Automatic Vehicle Identification (AVI), resources can be more efficiently utilized and the government can focus on safety-related ITS services. This is the reason for shifting policy.

At this time, the government, which is utilizing the private traffic information, should continuously verify the reliability, quality, and stability of the private data sources. In particular, the National Traffic Information Centre receives and redistributes the private company data without any additional processing. Therefore, if the quality control of traffic information is not done properly by the private company, the National Traffic Information Centre may be responsible for any complaints related to data quality. In other words, it is required to continuously monitor the quality of private traffic information in addition to the public traffic information.

Monitoring quality by comparing private traffic information to public traffic information on standard links that have a certain degree of completeness and accuracy of public sector data could be one of the alternatives. In addition, it will be easier to secure the reliability of information if the National Traffic Information Centre can receive additional information such as the number of collected samples, in addition to traffic information which is processed and handled by a private agency.

This type of probe-based traffic information service, its expansion to public usage, and the oversight efforts in Korea may shed light on the direction for other countries who may lack the government budget to initiate traffic information services. Using this type of approach, the government can save costs associated with traffic information collection and the private sector can also be benefited from the public subsidy for deputizing government's roles.

Further information:

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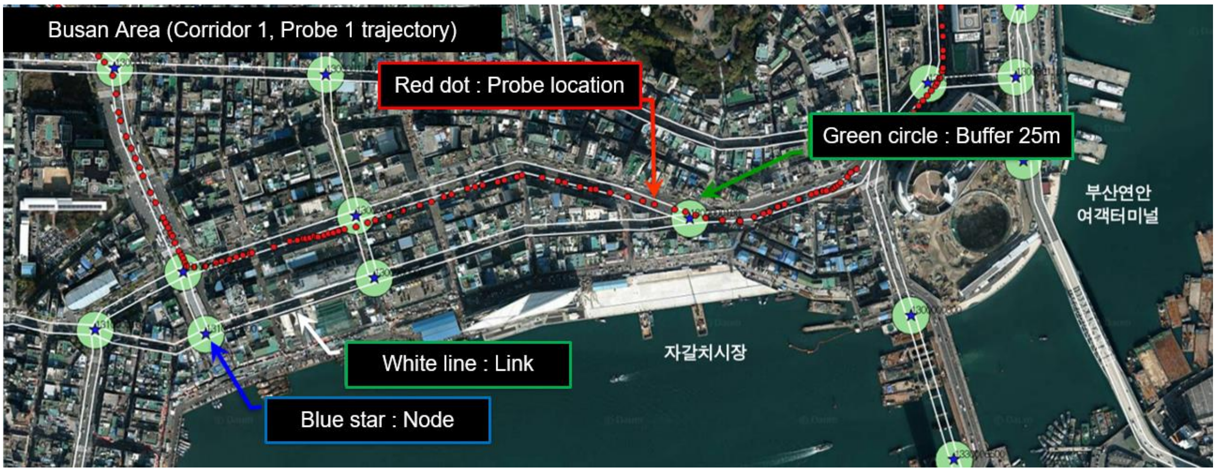
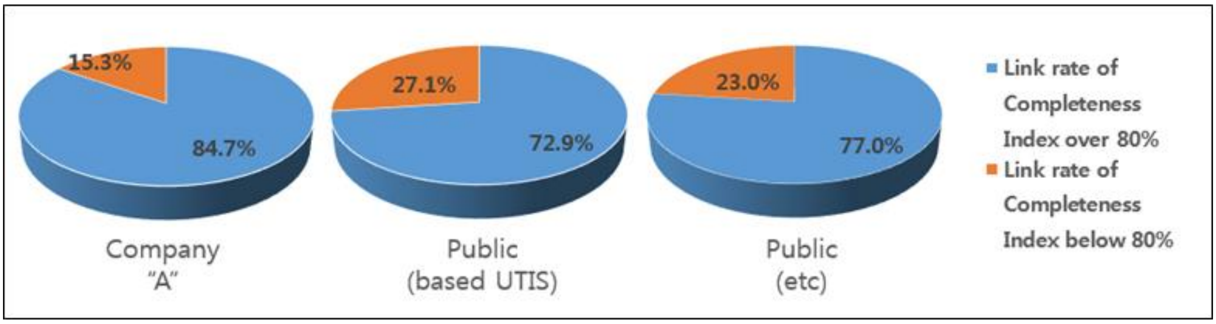


Figure 1. Prove vehicle Travel Record (Example)



* Company "B" has 97.0% completeness of all standard links

Figure 2. Analysis Result of Traffic Information Completeness

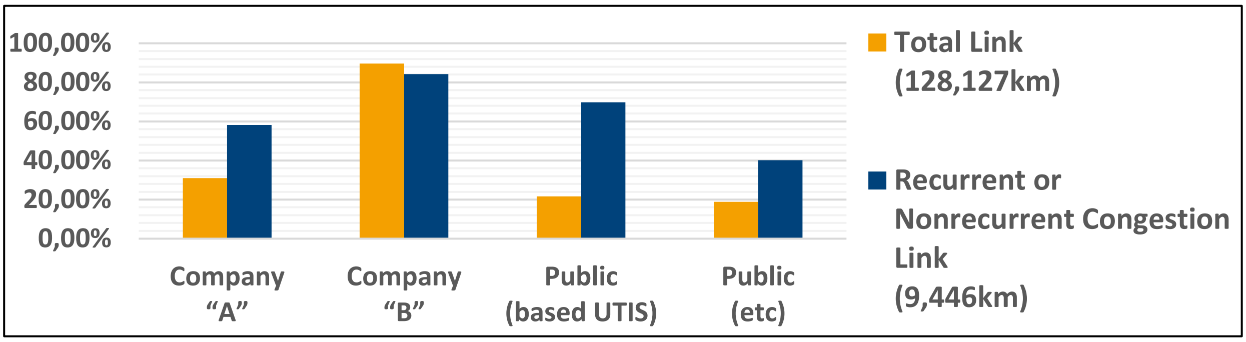


Figure 3. Analysis Result of Traffic Information Coverage

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