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THE CONNECTED VEHICLE

FISITA

WORLD ROAD ASSOCIATION
MONDIALE DE LA ROUTE
AIPCR PIARC

STATEMENTS

The **World Road Association (PIARC)** *draws its membership from governments, regional authorities and others involved in the planning, construction, maintenance and operation of roads and highways. It is a non-political and non-profit making association established in 1909, after the first International Road Congress held in Paris in 1908. The World Road Association was granted consultative status to the Economic and Social Council of the United Nations in 1970. PIARC plays a leading role in the exchange of knowledge on roads, road transport policy and practices.*

The **International Federation of Automotive Engineering Societies (FISITA)** *is the world body representing automotive engineering. It is a federation of the major engineering societies in 38 countries. It undertakes the exchange of technical knowledge on all aspects of vehicle design and manufacture. It has an important role in the exchange of leading-edge technologies between nations, helping to create efficient, affordable safe and sustainable automotive transportation for the benefit of all.*

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 organizations or agencies.

This report is available from the internet site of the World Road Association (PIARC)

http://www.piarc.org

and from the FISITA web site

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PREAMBLE

The World Road Association (PIARC) and the International Federation of Automotive Engineering Societies (FISITA) share the common goal to optimise road transportation through advances in technology for the benefit of society. In this spirit the two organizations have decided to co-operate, in 2007, with the signature by the Chief Executive of FISITA, Ian Dickie, and the Secretary General of PIARC, Jean-François Corté, a Memorandum of Understanding providing a framework for this co-operation.

PIARC and FISITA decided to jointly explore the opportunities that the connected vehicle could have on their business and, in particular, the relationship between the connected vehicle and road network management. The PIARC Technical Committee on Road Network Operations (TCB2), chaired by Martial Chevreuil, took the lead.

As part of its terms of reference, the committee was tasked to explore the relationship between the next generation of connected vehicles and the road infrastructure and to consider the changes required to the way roads are managed. The committee foresaw a growing demand for policy guidance for road operators around the world to assist with planning and investment in order to make the most of the opportunities for greater safety and efficiency. It also identified demands from the automotive industry to understand the role of the road manager and ways to realise the benefits of working more closely with road operators.

Working with FISITA, PIARC Technical Committee B2 developed the concept of a Joint Task Force to take this initiative forward. At FISITA's annual congress in Munich in 2008 the then FISITA President, Christoph Huss (Vice President for Development Abroad, Type Approval and Traffic Management at BMW Group), restated his goal that FISITA should "re-focus the co-operation with other global transportation players". The formation of the Joint Task Force with PIARC was endorsed by the FISITA board.

The JTF adopted an independent, commercially neutral, "committee of enquiry" approach to its work. Members formulated a set of questions and put these to experts at workshops and conferences in different parts of the world. They undertook a set of telephone interviews and meetings with industry experts from the automotive and telecommunications industries.

The JTF considered the issues that needed to be addressed in order to encourage the appropriate, cost-effective and long-term deployment of connected systems. They considered the commercial case for investment in co-operative systems; the public case for deployment of these systems; the telecommunications environment; the political, financial, legal and operational challenges to deployment and the likely impact on highway and road network operations practice.

This report from the JTF is aimed at policymakers, directors and senior managers in Roads Administrations, the automotive industry and other industry organisations. It consists of five self-standing discussion papers bound together by an introduction. The findings are published on the PIARC and FISITA websites and will be presented to the engineering and academic *communities through an outreach programme and at each of the FISITA and PIARC World Congress.*

In line with PIARC policy, members of the JTF give their time voluntarily, free of charge. It is international, non-commercial, undertakes no research and shares its advice openly. The opinions expressed reflect the evidence given to the task force, not necessarily the views of task force members or those of their organisations. The task force is chaired by Robert Cone, former Director for Roads for the Welsh Assembly Government.

On behalf of our two organisations, PIARC and FISITA, we welcome this report and express our appreciation of the efforts of all who have contributed to its preparation.

Signed by

Jean-François Corté
Secretary General
World Road Association

Ian Dickie
Chief Executive
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The joint task force was chaired by Robert CONE (United Kingdom), member of the PIARC Technical Committee B.2 Road Network Operations.

The report was edited by Richard HARRIS and John MILES (United Kingdom) with the contribution of the following participants to the joint task force.

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CONTENTS

EXECUTIVE SUMMARY

The advent of Intelligent Transport Systems has provided new opportunities for improving the safety and efficiency of the road network. The development of intelligent vehicles, connected by wireless networks to the roadside infrastructure, brings opportunities and issues. The World Road Association (PIARC) Technical Committee on Road Network Operations anticipates a growing demand for guidance for road managers who have to make long term investment decisions. It also identifies a demand from the automotive industry to understand the role of the road operator and the benefits of working more closely with road operators.

In 2007, a group of highways and traffic specialists from the PIARC Technical Committee began dialogue with automotive engineers from the International Federation of Automotive Engineering Societies (FISITA) on these issues. A formally constituted Joint Task Force (JTF) with nominations from both organisations was formed the following year. The JTF has been considering the prospects for advanced vehicle-highway systems that take advantage of more intelligent, connected vehicles and an intelligent road infrastructure.

Subsequently the JTF undertook a series of workshops with road managers and representatives of the automotive sector. Members of the JTF made presentations and received comments at a series of industry conferences. Finally the JTF held one-to-one telephone interviews with representatives of the automotive and telecommunications industries. This report is the outcome of this dialogue.

The report is addressed to policymakers, directors and senior managers in roads Administration, the automotive industry and other associated organisations. It takes a high-level view of current developments. It considers opportunities to exploit the potential of connected vehicle technology, either through commercial enterprise or to achieve progress with public policy goals. The material presented is a distillation of the views expressed by those consulted and does not necessarily represent the views of the editorial team.

The report is divided into five parts. **Chapter One "*From conception to reality*"** provides an introduction to current developments. Throughout the world regions share the same issues. There are too many vehicles trying to use capacity-limited roadspace at the same time. Road congestion affects economic performance and quality of life. Road casualties spoil lives and place a burden on society. Excessive emissions from road vehicles contribute to climate change. Each region is exploring a different approach to using Intelligent Transport and IT to provide some solutions to these problems. Research and development programmes in Europe, Japan and North America have demonstrated the potential of the technology to contribute to solution to all of these issues.

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The task force found that the connected vehicle is no longer a research concept but a reality, with applications that fall into four different, but not necessarily separate, areas:

1. connected vehicle safety applications. Examples include driver advisories, driver warnings, and vehicle and/or infrastructure controls;
2. connected vehicle mobility applications that use real-time data. The data are transmitted wirelessly and are used by information service providers to broadcast current traffic conditions for satellite navigation systems. Such data potentially also has value to the network manager for planning and managing the network; and to traffic engineers for optimising the performance of the transportation system;
3. connected vehicle environmental applications that use real-time data from vehicles to support the creation, operation, and use of "green" transportation options by system operators and users; and
4. commercial applications which enhance the way business is conducted and open up new market areas e.g. for location-based added value services.

Chapter Two "*The commercial perspective*" of the report provides an analysis of the issues arising from the development of the connected vehicle from different business perspectives: the automotive industry; IT and telecommunications; digital mapping and information services; and equipment and control system suppliers.

Each of these businesses have to adapt to the connected vehicle as a completely new user environment, which brings together the home, the car, business and the mobile internet. Even at this early stage of development applications which enhance navigation and provide services to drivers are available and in use. Furthermore, the widespread availability of affordable aftermarket navigation systems and the advent of the smartphone means that such services are no longer confined to top end vehicles.

The automotive sector seeks a clear legal and regulatory framework so that they can develop and introduce the next generation of products and services. They need to be able to establish relationships with road managers so that data and information can be easily shared in a standard way. They have to be prepared to provide services for the next generation of connected, IT literate customers.

Telecommunications companies continue to improve global coverage and invest in development and deployment of the next generation technologies. They are driven by competition to develop more bandwidth and more responsive systems. This is a time of rapidly changing technology challenging the automotive and road industries which operate on relatively long production cycle times.

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Part Three "*The public sector perspective*" considers the issues arising from the development of the connected vehicle and co-operative driving systems from a public policy perspective. It considers whether the connected vehicle will impact positively on all road transport. From a road network operations perspective the case for investing in the connected vehicle and co-operative systems will be based on safety benefits, improvement in operations and fewer traffic law violations. Other benefits will come from a more complete understanding of user demand through data from the connected vehicle, which will enable more efficient use of the network. Developments that will enable flexibility in road pricing, emissions monitoring, and crash avoidance will also be welcome. The connected vehicle will achieve an impact on CO_2 and environmental issues in a number of ways, primarily by reducing congestion thorough better journey planning and by reducing fuel consumption by fostering smoother driving, with less wasted mileage because of smarter navigation.

The social, political and legal issues that road networks face are diverse and can vary greatly not only from country to country but also on a regional scale. The available evidence points to a prima facie case for action by governments to exploit the technology based on improvements in road safety and by road operators based on greater efficiency in maintaining and operating roads and benefits to the overall economy. The arguments are multi-faceted and, in difficult economic times, are not yet sufficiently convincing to result in large scale deployment plans. Policymakers are, instead, focussing on government-sponsored development and demonstration schemes.

Part Four "*Issues affecting deployment*" explores in greater depth a number of issues associated with the spread of connected vehicles, the deployment of co-operative systems and the initiatives which are being taken by industry, policymakers and road operators in response.

The choice of technology is a critical issue. Cellular data systems are available throughout the world and provide support for most applications but do they provide a sufficiently reliable and responsive service for safety applications? Dedicated short range systems have been developed which are optimised for these services, but who will pay for the deployment of the infrastructure? Commercial technologies are developing fast and the next generation is already being deployed. How long will it be before these services can support machine to machine communications? Is a hybrid solution the answer?

There are other issues which will affect the speed of deployment. For these applications to be fully exploited the legal and regulatory environment has to be appropriate and understood. Standards have to be in place and system architectures established.

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Part Five "*Where next?*" brings together key points from previous chapters and offers some pointers from the Joint Task Force on the way forward. Why should governments and road managers invest in infrastructures for vehicle communications? Whilst the market will deal with the deployment of services, infotainment and information systems, authorities have the responsibility of establishing the case for safety systems, providing the regulatory environment, ensuring uniform coverage and increasing the pace of adoption.

These papers provide a snapshot of the development of the connected vehicle and its environment in 2011. The technology required is developing rapidly and provides opportunities for improving the quality of life and the environment. The industries involved can develop and deploy the technologies but require a clear operational framework. The key to success is collaboration at local, regional and international levels and the task force welcomes recent collaborative initiatives involving a wide range of international organisations. This is a global industry.

Whilst these issues have been discussed widely within the automotive and ITS environments the Task Force found that there remains a need to provide impartial advise to policymakers and non-specialist managers about the opportunities and issues. There is a need for further collaboration between the automotive sector and the road management sector to maximise the opportunities for the exchange of information about road and traffic conditions.

The interest shown at the 24th World Road Congress in Mexico in 2011 illustrated the interest in this subject and demand for more communication and discussion within the world management community. The PIARC and FISITA membership are well placed to follow these discussions and exploit new relationships between the automotive sector and road managers to put in place the foundations for new ways of managing our roads and environment.

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PART ONE – FROM CONCEPTION TO REALITY

SETTING THE SCENE

In most countries the modern road network has developed gradually over the last 80-100 years. The first traffic signals appeared in the 1920's and the autobahns in Germany set out the future for high-speed strategic roads. Many of today's road networks use technology and IT for the planning and maintenance of the network and computers control networks of traffic signals and signs providing information to drivers.

For many years the basic form of the vehicle has remained unchanged, albeit becoming more efficient and comfortable. However, in recent years, the introduction of computing and control technology has had a radical effect on vehicle performance. The vehicle is now a complex machine using networked computing to optimise almost all its functions. It has sensors which are monitoring many facets of its environment and vehicle systems which provide assistance to the driver in a number of different ways. However, the driver remains in control.

Over the same period of time the driving environment has changed significantly. All over the world motor vehicles are a necessary part of most people's lifestyles and play an important part in the economy. Most driving takes place in a mixed and busy environment with many distractions. Congestion is normal, efficiency improvement and carbon reduction essential, safety is paramount and road casualties are not acceptable.

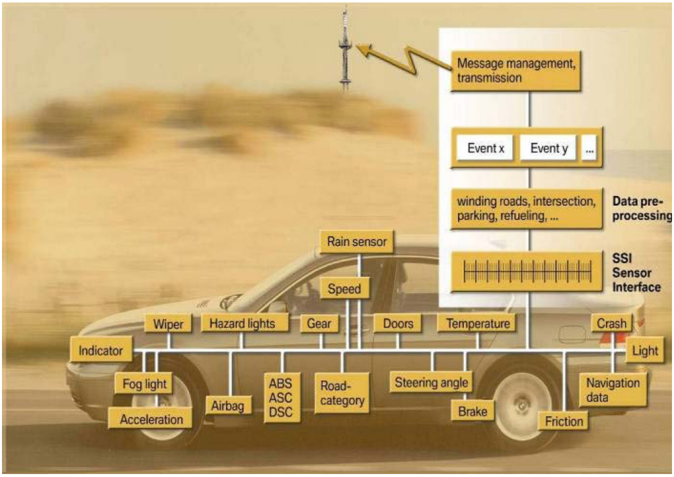
Governments and road managers have made significant investment in the road asset. Highway and traffic engineering has improved roads and the network has been softened to reduce the severity of crash impacts. Drivers are better educated and enforcement systems have been developed to encourage drivers to obey the rules, particularly with regard to traffic signals and speed limits. However, accidents still occur and despite advances in road engineering, softened infrastructures and careful vehicle design there is an unacceptable casualty rate.

Over the last 20 years researchers and engineers have started to explore the opportunities for achieving greater improvements in safety without reducing mobility. The vision was to produce a vehicle which does not crash. Research programmes in Europe (DRIVE, PROMETHEUS) explored the use of wireless technologies to communicate between vehicles and between vehicles and the roadside, demonstrating the value of assisting the driver and providing advance information. These are complex problems and require a holistic approach encompassing the infrastructure, the vehicle, the driver and their interactions. In the 1990's connected technology was taken a step further with the IVHS programme culminating in a demonstration of autonomous driving in platoons on the I95 in San Diego California in 1995. At the same time in Japan the SmartWay programme set out plans for the deployment of connected systems for providing driver information.

These developments point to a future in which the vehicle has the potential to be connected to other vehicles and the infrastructure to form part of an integrated system. This system can be much more efficient, environmentally friendly and safer. The driver remains the key player. Society demands that the driver remains in full control of the vehicle and fully responsible for its actions and consequences. The challenge for policymakers and road operators is to introduce an environment in which the technologies work with the driver for the benefit of all.

THE POTENTIAL OF CONNECTED TECHNOLOGIES

Today's vehicles are complex machines. Networked computing is now built into the operation of many parts of the vehicle. Engines and transmissions are managed by electronic systems. Suspension systems are optimised for the conditions, managing ride height, ride quality and handling. Body functions, security, entertainment systems and lighting are optimised and, perhaps most important in the context of the connected vehicle, the interface with the driver is managed by computer. These systems can create data and the vehicle can store the history of events in its memory.



The intelligent car (Source BMW)

Add wireless communications and there is the opportunity to share this information with other vehicles and the infrastructure. A vehicle can broadcast data describing its position, movements and highlighting manoeuvres, and share this with other vehicles to prevent collisions and the infrastructure to optimise traffic control.

The ability to receive information enables a new approach to assisting the driver. Intelligent vehicle systems can combine information from navigation systems with data from on-board sensors and information received from the infrastructure. Using this information the vehicle systems derive an awareness of the immediate surroundings, including areas which may not be visible to the driver, which can be used to assist the driver to drive more safely. If the vehicle systems anticipate an accident they can, as a minimum, prepare safety systems and, perhaps, intervene to prevent an accident.

The same information can be applied to make vehicle systems operate with increased efficiency. It can be used to encourage drivers to drive in a fuel efficient way. But integration with the infrastructure creates new opportunities. Under development are applications which communicate with traffic control systems and traffic signals so that the vehicle can be directed along the most efficient route and join "green waves"[1] and be provided with the appropriate speed to travel to remain with the green phase. This is particularly valuable for the efficient performance of heavy goods vehicles.

Wireless communications also enables the development of a wide range of other applications. Knowledge of traffic speed and weather referenced to geographic location is valuable to the network manager and, when validated and processed, can be shared with other road users, reducing delays and mitigating congestion. Geographically referenced vehicle data about road surface condition and friction also has the potential for use for network assessment and road maintenance planning.

Connecting the vehicle to the world outside also enables many commercial opportunities. OEMs and the after-market companies are developing new interactive customer services and novel business models aimed at developing new markets. These possibilities are discussed in Part 2 of this report.

Regardless of the type of vehicle it has become clear that there are different, but not necessarily separate, types of connected applications:

- connected vehicle safety applications that increase situational awareness and reduce or eliminate crashes through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) data transmission. Examples of vehicle safety applications include driver advisories, driver warnings, and vehicle and/or infrastructure controls;
- connected vehicle mobility applications that use real-time data captured by a network from equipment located on-board vehicles and within the infrastructure. The data are transmitted wirelessly and can be used by the road operator and traffic engineers in applications such as variable speed limit signs and congestion warnings, to optimise the performance of the transportation system. Such data also has value to the network manager for planning and managing the network.
- connected vehicle environmental applications that use real-time data from vehicles to support the creation, operation, and use of "*green*" transportation options by system operators and users. For instance, environmental applications might advise

[1] Sections of traffic signals linked such that vehicles can pass through the section without stopping.

Ubiquitous Wireless Communications (Source – CVIS)

drivers about how to save fuel with changes in maintenance and driving style. Environmental applications can also help integrate travel by personal vehicles with public transit, or help drivers plan trips for off-peak times; and

- commercial applications which enhance the way business is conducted and open up new market areas e.g. for location-based added value services.

At the present time some of these applications can be delivered using the 3G cellular data network. Some are already available in an early form.

The safety related applications require a faster and more reliable service than can be provided by these data systems at the present time. A special form of short range wireless (known as DSRC) has been developed to deliver these applications, but except for road tolling this type of network has only been installed in significant amounts in Japan[2].

A GLOBAL PERSPECTIVE

The automotive industry is a global industry. Vehicle manufacturers seek economies of scale through providing common products world wide. Cities and regions around the world share many common issues. Vehicles, particularly haulage, need to be able to circulate within regions without modification. However, regional and national differences exist with regard to social and economic conditions, terrain, extent of highway development, traffic law and driving behaviour. The local context will require different solutions.

[2] SmartWay, http://www.nilim.go.jp/japanese/its/3paper/pdf/060131trb.pdf

Europe

The European Union (EU) comprises twenty seven sovereign States, each with its own legislative and judicial bodies. It is the national and regional authorities, not the EU, that are responsible for and control highways and traffic, the police, ambulance and rescue services, as well as all other social services, inside their own borders. In this sense, there is no difference between countries belonging to the EU and non-members, like Norway, Switzerland, Serbia, Ukraine or Russia.

Most public research is sponsored by National Governments, the European Commission (EC) or both. Usually research work is carried out by a consortium composed of companies, cities or regions and academic organisations. EC co-funded projects such as SAFESPOT[3]; COMeSafety[4]; CVIS[5]; and PreVent[6] have explored issues related to vehicle-to-vehicle and vehicle-to-infrastructure communications as the basis for co-operative intelligent road transport systems and this work in being continues in the current generation of projects such as DRIVE C2X[7]; HeERO[8]; Ecomove[9]; FREILOT[10]; and Instant Mobility[11].

Looking at the implementation of in-vehicle services by four companies that offer factory-installed, embedded two-way communications systems in Europe (BMW, Fiat, PSA and Volvo Cars), their roll-outs have been on a country-by-country basis. Each of these companies is working with its own constellation of central in-vehicle service provider, linked with local call centres and service providers.

Traffic information, an important service that is supplied as part of the in-vehicle systems, is also collected and distributed by both public and private organisations in their respective countries. Already there are fleets of heavy goods vehicles equipped with GPS for automatic vehicle location reporting point-to-point journey times across the continent. Moreover a growing number of countries are adopting electronic tolling systems for trucks which rely on dedicated short-range roadside to vehicle communications or satellite positioning.

Private companies and associations delivering roadside assistance and security services to drivers also operate within their respective national or regional borders. Companies that claim to offer pan-European services, like Mondial Assistance or Securitas, are registered and operated on a country-by-country basis.

The European "*ITS Directive*" (Directive 2010/40/EU of 7 July 2010) provides a legal framework for the deployment of Intelligent Transport Systems and services across Europe. One of the priority areas for development under the Directive are the technical

[3] *www.safespot-eu.org*
[4] *http://www.comesafety.org*
[5] *http://cvisproject.org*
[6] *http://www.prevent-ip.org*
[7] *http://www.drive-c2x.eu/project*
[8] *http://www.heero-pilot.eu*
[9] *http://www.ecomove-project.eu*
[10] *http://www.freilot.eu*
[11] *http://www.instant-mobility.eu*

and operational specifications for linking the vehicle with transport infrastructure. Member States that deploy co-operative systems within scope of the Directive will need to comply with European specifications made under the Directive. The European Council and Parliament have the right to object to any specification before it is adopted. One of the priorities is eCall[12], a pan-European in-vehicle emergency call system which uses the single European emergency number 112[13] in the event of an accident which will allow its interoperability throughout the European Union.

A paper, ITS Issues in European Countries; Regulations and Practices by Michael L. Sena, a member of this Task Force, deals with these issues in more detail. [***http://www.vt.bv.tum.de/eyeos***]

USA

The US Department of Transportation has a three part programme researching and testing connected vehicle systems.

Technical work is underway to develop an architecture for connected vehicle systems that provides for use of many communication media. Standards development has been underway for years and the US is aggressively developing standards for the connected vehicle environment. The US is working co-operatively with the EU to harmonise appropriate standards. Further, the USDOT sponsors an operational test-bed that is available to public agencies, universities and private companies who wish to test products and services in a connected environment.

Based on connected vehicle technologies, applications are under development that address safety, mobility and the environment. Safety work focuses on V2V and V2I applications. The V2V program is the most advanced with a large-scale safety pilot and model deployment starting in 2012. Data from the safety pilot will be used to inform an agency decision by USDOT's National Highway Traffic Safety Administration (NHTSA) on possible regulatory action. That decision is planned for 2013. Additionally, V2I applications are being researched. The research centres on traffic signal applications that would use signal, phase and timing (SPaT) information for safety warnings.

The third part of USDOT connected vehicle research is in the policy area. There are many complex issues which must be addressed for implementation of connected vehicle technology. One of the more significant issues centres on the security system that will be necessary for V2V (it would also be used for V2I safety applications). A secure certificate system will be needed for V2V integrity. Associated issues concern the type and extend of infrastructure that is likely for V2V, who may be the owner/

[12] ***http://www.ecall.fi/Position_papers_DG_eCall_v2.pdf***

[13] ***http://ec.europa.eu/information_society/activities/112/index_en.htm***

operator of the infrastructure and how it would be financed. Other issues concern privacy, liability, and cyber security.

The USDOT research programme makes use of co-ordinated research, testing, demonstration and deployment. The Federal research investment is targeted to areas that are unlikely to be accomplished through private investment because they are too risky or complex. The research program is carried out in full co-operation with the automotive industry through the Co-operative Automotive Metrics Partnership (CAMP) and the VII Coalition. Other stakeholders, including a number of State administrations, the automotive suppliers, and consumer electronics companies, also are researching and testing connected vehicle technologies and applications so that the transportation community can realise the full potential and vision of the connected vehicle.

The US programme is a major initiative of the Intelligent Transportation Systems (ITS) Joint Programs Office (JPO) at DOT's Research and Innovative Technology Administration (RITA) in coordination with US DOT modal administrations. Full details are available at ***http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm***

Japan

In "*SmartWay*[14]," the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been promoting the deployment of next-generation roads in order to implement a policy of improved traffic safety, reduced congestion, and environmental protection. In January 2011, on the basis of the results of "*SmartWay*", a new ITS service called the "*ITS Spot service*" was started on the Bay Shore Routes of the Tokyo Metropolitan Expressway. By March 2011, the service had been expanded into 1600 points, with a focus on expressways.

(Note that because of the great Tohoku earthquake, the development of these services have been delayed in some parts of eastern Japan.)

The Tsunami in March 2011 provided a case study of a connected vehicle application. The authorities in Japan set up a liaison with the Automobile companies so that they could access vehicle derived information about closed roads and pass it on to other road users.

The ITS Spot service provides large-scale road traffic information and information to promote safe driving by means of DSRC with car navigation systems compatible with ITS Spot. Some model can be used to provide tourist information and updated maps. Car navigation systems compatible with ITS Spot have been released by each company. In the future, the government and the private sector will construct an open platform to realise various ITS Spot services.

In May 2010, the government's IT Strategic Headquarters published its "*New Strategy in Information and Communications Technology*." The strategy involves advanced

[14] http://www.nilim.go.jp/japanese/its/3paper/pdf/060131trb.pdf

information and communications in the fields of roads and traffic. IT Strategic Headquarters has established an ITS task force, which examines the installation of systems to support safe driving, the provision and collection of road traffic information, and the promotion of Green ITS. In Japan, IT Strategic Headquarters handles the development of road maps and their co-ordination among the ministries; the ministries formulate policy measures.

MLIT concluded memorandums of co-operation in the field of ITS with US DOT/ RITA (the Research and Innovative Technology Administration of the Department of Transportation of the U.S.A) in October 2010 and with DG INFSO (Information Society and Media Directorate-General) in June 2011. On the basis of these memorandums, Japan, the USA, and Europe will promote co-operation in the sharing of research and development information, clarification of fields of co-operation, and support for international standardisation.

China

China's economic growth has resulted in a rapid increase in the number of vehicles using its roads, with the inevitable consequence of congestion, collisions, pollution and economic costs. In most cities in China the average speed has dropped to less than 20 kph, and as low as 7-8 kph in some.

In November 2008 the Chinese government announced a 4 trillion Yuan (0.7 trillion USD) package of investment in railways, highways and airports. China has 65,000 km of expressways and expect their network to surpass that of the United States by 2011. Rapid development of their ITS industry over this period, driven by government led projects is expected. It has been estimated that the ITS market is worth around 18 billion Yuan, (2 billion USD) increasing at about 30% per year.

Research in China is focussing on traffic control through the sharing of information and improved emergency management systems. Automatic driving is also on the research agenda.

South Africa

South Africa has transport challenges no different to those experienced in many other countries. There is an "*adapt and design*" approach to developing a national transport system that will facilitate and sustain economic growth. A National Planning Commission to develop Vision 2030 has been mandated to develop a long-term vision and a national strategic plan. This diagnostic report will assist in analysing the key challenges that confront South Africa. Other initiatives include the 25 year transport plan and a recent transport investment conference to address the overall spectrum of transport and investment need.

The South African National Roads Agency Ltd (SANRAL) is responsible for managing 16 170 km of the national road network. South Africa's travel needs are complex.

SANRAL's declaration of intent (DOI) 2009-2012 emphasises the need and importance of engineering and technological innovation to support excellence. In particular one of its strategic objectives is to deploy intelligent transport systems (ITS) to improve long-term management and effectively manage its national resource, making its roads safer and more efficient. SANRAL recently engaged in a comprehensive assessment of its overall Intelligent Transportation System Program to enhance the level of benefit it was delivering to the travelling public in the major and high-density metropolitan areas.

The majority of vehicles travel on the well-developed road network in the metropolitan areas. There are high quality national (and tolled) roads managed by SANRAL/concessionaires and hence there is a high level of maintenance, support and patrolling. Recent projects like the Open Road Toll Project, which has been implemented on 185km of the freeway network as an initial phase, is an example of a vehicle mobility application where real-time data is captured from equipment located on-board vehicles and within the infrastructure. This data will be used by the road operator to manage and optimise the network with a focus on traveller information dissemination to support its Advanced Traveller Information System (ATIS).

South Africa's vehicle fleet is a combination of both old vehicles and high end models from European manufacturers and all other OEMs, including the US and Japan. Some models are locally assembled (e.g. C class Mercedes) built to an international specification with same level of technology as those produced models available elsewhere in the world. Broader connected vehicle deployment will depend on the after-market sector whilst installed applications will experience growth through new high-end vehicles.

Given the automotive bias, it should be noted that South Africa is the 4th country in the world where one of the GPS service providers has launched its new generation of (semi) real-time traffic updates. Probe vehicle input provides traffic data that are updated every two minutes and downloaded to the on-board units that provide updated and very accurate predictive travel times and has the ability to suggest alternative roads.

There is wide spread mobile phone (GSM) coverage on most roads. There is also an MPT1327[15] standard trunked radio network with "*umbrella*" coverage in some areas and good coverage along the main routes. The latter is using primarily for data communication and fleet management.

Accident statistics are alarmingly high in developing countries, including South Africa and the connected vehicle "*thinking*" may be a driving factor from a safety perspective. Cost benefit has still to be proven. This will be require further research and the consideration of current technological developments to support safety and the connected traveller in South Africa is being explored.

[15] An industry standard for trunked radio communications networks.

Australia

Leadership in the field of Co-operative Vehicle Highway Systems in Australia was initiated by Austroads, under the label of Co-operative ITS. Austroads is the association of Australian and New Zealand road transport and traffic authorities and aims to promote improved road transport outcomes.

In April 2009 the Board of Austroads established the Co-operative ITS Steering Committee and an Industry Reference Group. Activity to date includes working with the Australian Media and Communication Authority on the allocation of the 5.9 GHz band to Co-operative ITS. Austroads recently published research report AP-R382/11 DSRC Interoperability Study[16].

Austroads has published Report AP-R375/11 on the potential safety benefits of collision avoidance technologies through vehicle-to-vehicle DSRC in Australia. This report by the Monash University Accident Research Centre estimates potential benefits as a reduction of casualty crashes by 25 – 35% subject to significant take up in the vehicle fleet[17].

A comprehensive exploration of a wide range of policy and operational issues requiring addressing for successful deployment has commenced. Policy issues include the understanding of functional responsibilities, liabilities and governance for effective service delivery; the need for interoperability, concerns about privacy, security and vulnerability to attack and misleading advice. Technical issues include the reliability and accuracy of positioning systems, and the abilities of communications technologies to provide the required service.

The after-market sector will be important in Australia, as originally installed applications will only be available through new and imported vehicles, and this will be a relatively slow process for introducing the new technologies. Retro-fitting of applications to the existing fleet could occur before enabled new vehicles are available in sufficiently large numbers on our road system to be effective. The key area of risk is that the after-market sector may introduce problems that are more controlled in the original installed equipment sector. The Human-Machine Interface (HMI) is a key risk area. Once vehicles with co-operative ITS are on the road, the issues of ongoing maintenance and roadworthiness become important. A report relating to the introduction of cooperative ITS to Australia has been published by Austroads[18].

[16] Available at ***www.austroads.com.au***

[17] Available at ***www.austroads.com.au***

[18] AP-R383/11 Examination of Major Policy Issues Relating to Introduction of Cooperative ITS to Australia, available at ***www.austroads.com.au***

SUMMARY

Research has shown that connected vehicle technologies promise to improve safety, efficiency and journey comfort for drivers. They contribute towards reduced emissions and congestion. The availability of this technology will allow road managers to develop new, more efficient ways of managing. The automotive and navigation sectors are already exploiting the potential of connected vehicle technology using the commercial 3G telecommunications networks which are available over most parts of the world.

Although telecommunications are standardised different regions of the world have different infrastructures, social structures and road infrastructures. However, they share the same issues of a large number of vehicles trying to use a limited infrastructure, the resulting congestion affecting quality of life and emissions contributing to waste of fossil fuels and climate change.

Each region is exploring a different approach to using Intelligent Transport and IT to provide some solutions to the problem. In Japan the approach is to plan the roll out of connected systems using a combination of mobile telephone technology, microwave (DSRC) and infra-red. Japan has already achieved a significant user base. In the US the government has set out a research strategy leading the rollout of systems designed to improve safety and efficiency. Europe includes a set of nations, some of which have highly organised and safe roads and others which are seeking to come up to the same levels of management and safety. Research in Europe is focussed on the development of systems which will improve safety and efficiency.

International co-operation between Europe, USA, Japan and Canada is being facilitated through agreements that commit the participants to work together and share information on issues associated with co-operative systems including standards development.

A review of research on connected vehicles and co-operative systems carried out for the Joint task Force by the Technical University of Munich (TUM), can be found at [***http://www.vt.bv.tum.de/eyeos/***]

THE COMMERCIAL PERSPECTIVE

BACKGROUND

The issues arising from the development of the connected vehicle from different business perspectives are many and various. Trials have shown that the connected vehicle promises more than enhanced safety and improved journey times. It opens up commercial opportunities for the automotive industry Original Equipment Manufacturers (OEMs), provides a new market connected vehicle applications ("*aps*"), new business opportunities for navigation companies and transforms the vehicle into a telecommunications platform to be exploited by the telecommunications industry.

Most of the research undertaken has focussed on the safety, capacity and efficiency and environmental benefits. These are benefits to individuals and to society as a whole but not necessarily profitable to the companies themselves. The commercial challenge is to work out how to bring these co-operative systems to market around a business case that makes sense for all the stakeholders, particularly the automotive industry.

Up to now the telematics boxes for cars have been stand-alone solutions which are developed for different OEMs. Integrated solutions will be more of a challenge, to integrate or interface between the boxes for different OEMs; also for interfacing between low-value and high value cars.

Co-operative applications need stable long-term technology - for the life-time of the vehicle. Co-operative driving will need internationally harmonised standards and trust protocols for communications between vehicles and with the infrastructure. Safety systems will need very reliable low-latency communications with a split-second response. Current thinking favours installation of dedicated short-range communications (DSRC) but 4^{th} and 5^{th} generation cellular networks will soon provide other communications options. The technology itself need not be a barrier to deployment.

It is unclear at this point what type of technology will be appropriate for the security network, who would own and operate it or how it would be funded initially and for ongoing operations. The long-term costs of fitting all vehicles with DSRC communications would not be high, but supporting roadside infrastructure for the security or certificate systems will be needed for ultimate implementation of V2V.

Infrastructure for V2I applications may have more flexibility although few roads authorities currently have plans to put in infrastructure needed for V2I unless it can be incorporated into traffic signal upgrades. Japan is a notable exception in rolling out an extensive network of DSRC beacons at 5.8 GHz. The USA is due to take a decision on this point very soon.

THE AUTOMOTIVE SECTOR

In the meantime the automotive industry is moving forward adding autonomous safety and mobility features to their cars. These are both practical tools for drivers and marketing tools for the companies. They demonstrate that there is an appetite for the use of more advanced technology in cars and that the cost has been reduced to a point that it there is not customer resistance.

> Low-cost video cameras are now incorporated in some vehicles to provide information for driver assist functions. These cameras can read traffic signals and signs. But wouldn't it be better if the signals broadcast the information directly to the vehicle, cutting out the scope for error by the camera system and the driver?

Dominant issues for the industry are fuel efficiency, customer care, customer loyalty and infotainment. Manufacturers see new technology as a means of maintaining or improving their market shares with features that enable their products to be differentiated in style and equipment from the models of other suppliers. To some extent this cuts across government interest in having all vehicles carrying similar equipment functionality to enable a universal service available to all road-users.

Concerns about automotive safety are informed by a strong ethic of customer care. However, in practice, developments in vehicle safety systems and driver support are motivated by what is commercially viable. The industry is interested in market gains that are realisable in the short to medium term, hence they are focussing on connected technologies which make use of the available mobile telecommunications networks. At the same time development of nomadic devices and smartphone apps using mobile telecommunications is proceeding apace. The time from development to market for these devices is very short, less than a year. It is a major challenge for the automotive OEMs to get their business cycles to fit.

From a business point of view OEMs need applications to bring into the business plan quickly. There is industry-wide pressure to benefit from the globalisation of production by developing models that can be sold into different regional markets world-wide, with as much standardisation of equipment as possible. Short-term the focus is on in-vehicle consumer products that use mobile communications and GPS. In the medium-term the industry anticipates the commercial development of vehicle to vehicle communications.

The industry is actively seeking new markets in the form of added-value customer services. Service relationships are potentially a profitable growth area. A service relationship is long-standing, more so than just selling cars, trucks and buses. Margins for OEMs are being driven down on their products as they become more like commodities and so OEMs want more of the value chain accruing to them. New connected vehicle services already on offer to customers include:

- remote engine health management and vehicle diagnostics;
- emergency and breakdown handling;
- personal preferences and upgrading;
- event recording for insurance and claims;
- theft recovery and security; and
- entertainment, through the mobile internet.

Automotive insurance is another important business area. Once installed, GPS can be used for stolen vehicle tracking, automatic crash notification (eCall) and crash data management. Personal safety and security can be linked together as a service package. In Sweden, Germany, USA and elsewhere insurance companies are starting with a "*Pay as you drive*" concept. The data from in-vehicle telematics is powerful for user-based insurance profiling and has the benefit of GPS location referencing for incident analysis. The subsequent use of collected data which shows traffic flow, origin and destination information etc is normally aggregated to protect privacy before being supplied for other (non personal insurance) services. The prospect of changing driver behaviour through smarter analysis of personal driving profiles is one of the key potential benefits of these systems.

The pressure to avoid costly product recalls and litigation when things go wrong is major factor. There is an over-riding need to split the safety related applications from consumer applications so that basic vehicle functionality is not compromised. For example, the idea of having a docking station so that mobile devices and after-market units can connect with the vehicle's systems is an attractive concept, but is viewed with extreme caution. However, there is also a proposal that a smartphone will detect when it is within the vehicle environment and will switch automatically to a "*safe driving mode*".

> Where there have been delays in going to market, as with the automated emergency call service in Europe, eCall, it is because international, industry-wide service arrangements and back-office agreements have not been worked out. The OEMs have responded by introducing their own call centre based services for their customers.

Truck manufacturers are generally positive towards applications like lane departure warnings which help counter driver fatigue. However the freight and haulage industry operates tight margins and is notoriously resistant to any features increasing the capital and maintenance cost of a vehicle.

There are three significant applications for the connected commercial vehicle: Fleet management, emergency roadside assistance and stolen vehicle recovery. In Brazil and Mexico stolen vehicle recovery is required by law. "*Connection*" allows the incident to be dealt with, with speed and accuracy. It also benefits the security of shipping containers for freight.

In summary, the automotive industry is engaged in bringing connected vehicles to market as rapidly as possible, based on profitable consumer-led features (GSM, hands-free mobile phones, mobile internet, Infotainment). The business case, in the near-term, is based entirely on using existing telecommunications services rather than develop new dedicated systems. Connectivity is not just to the vehicle but enables connectivity though the value chain by adding partners. Embedded phones provide the basis for four main services: emergency call, traffic information, destination information downloads and remote diagnostics.

IT AND TELECOMMUNICATIONS

Progress with IT and mobile telecommunications is fundamental to the concept of the connected vehicle. Telecommunications Companies are investing billions of dollars in the telecommunications infrastructure and expect a return on investment in 3-5 years.

Having made a massive investment in mobile infrastructure for consumers the telecommunications industry is interested in exploiting that investment by selling bandwidth, hardware, applications and information services. There has been strong growth in cellular-based services into the vehicle, leveraging on the 2.5 and 3rd generation mobile phone networks. Companies are interested in connecting with mobile consumers to tap the revenue potential, for example from driving utility applications and location-based services paid for by advertising content, social networking and interactive games.

The connected vehicle is a new user environment that brings together home, mobile telephone and car. With mobile internet there can be rich content and social networking coming into the vehicle. Future generations of mobile telecommunications will further improve bandwidth, speed of communication and reliability. The long-term future of cellular phone systems has been agreed globally and is based on internet protocols. Fourth and 5th generation mobile phone networks will have the potential to create an "internet of things" (cars, smartphones and nomadic devices as terminals) each with a 1-2-1 interface with the customer.

> In future the connected vehicle will have many facets: One-2-Many (1-2-M): Personal device to Vehicle (D2V); Vehicle to Cloud (V2C) Vehicle to Infrastructure (V2I); Vehicle to vehicle (V2V); and possibly Vehicle to grid (V2G) for electronic propulsion. The cost of telecommunications connections will normally fall on the user or be offset by advertising revenues and fees for added-value services. Connection costs will be a major factor in the design of successful connected vehicle applications.

Along with the expansion of mobile phone networks there have been far-reaching developments in smartphone handsets and other nomadic devices. Many handsets now come equipped with GPS and digital maps. The number of models with advanced features is growing and retailers are offering them on attractive terms. Applications for them are easy to develop, for example to download maps and traffic information or to view Internet sites with traffic camera images, but there is no control over the quality of these applications. There are also serious safety concerns about the use of handsets when on the move because of the risk that driver will get distracted from the driving task.

Mobile phones are continuing to evolve. Handsets which incorporate near-field communications and DSRC are under development. Phone manufacturers are pressing for a standard to enable connectivity between the device and the vehicle, so that hand set controls are presented on the vehicle screen and can make use of the vehicle's HMI but vehicle manufacturers are cautious about the idea. Quality of the service is the issue, especially if the application is safety critical. They are concerned about the possibility of degrading the performance of the vehicles' own equipment.

With the growth in mobile bandwidth proceeding apace there is continuous content innovation and an insatiable need to increase capacity to service the development of new applications. Linked with this are new mobile tariffs and roaming charges. Products are updated every six months, affecting the choice of handsets and the bundling of services. In contrast the vehicle manufacturing cycle is 5 to 10 years and the lead-time on producing a new model from finalising plans to production is at least 30 months. Upgrades to the road infrastructure take much longer, from 10-20 years to work through.

This astounding pace of development in the telecommunications sector is fuelling the development of new businesses and is even having an impact on changing social conditions. Give the mismatch of product cycles the vehicle manufacturers will always lag behind and the road operators will be even further back. Experience with electronic tolling shows that new technology when applied to road traffic is adopted more quickly if there is take-up of after-market devices.

At the present time there is no evidence that there is a business case which will encourage the telecommunications industry to provide an infrastructure to support DSRC services.

In summary the road traffic environment take-up and adoption of mobile connectivity will be much quicker using existing portable technology and after-market devices. Developments in smartphones are significant, but they cannot rule out an independent in-vehicle platform in for safety-critical applications. Market-driven consumer applications alone are unlikely to produce large-scale safety benefits and there could even be disbenefits arising from driver distraction.

DIGITAL MAPPING AND INFORMATION SERVICES

Digital mapping and information services have been among the leading applications for the connected vehicle. Digital map providers are in partnership with mobile phone operators to expand the market for their products either in partnership with an OEM or by providing equipment for the after-market.

Advanced mapping systems are a platform for location-based services that can be sold into the vehicle. A great deal of innovation is expected around the so-called "*Freemium*" business model: free applications plus the map, based on selling air time and data transfer. Premium navigation services will be pay-per-use, with strong visual content such as realistic road sign graphics and 3D displays.

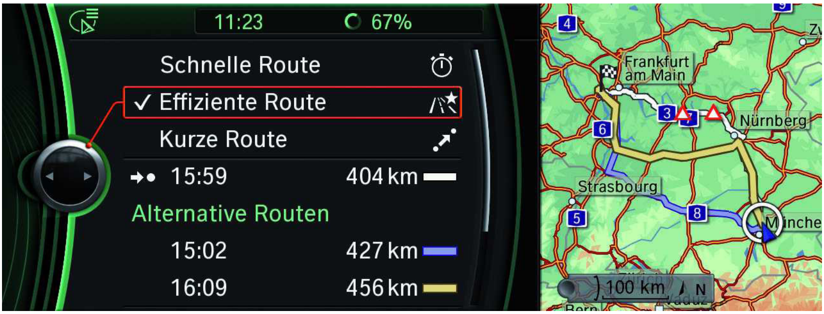
There is a close synergy between digital maps and information services. For example a major provider of digital maps also markets a traffic system that links real-time traffic information with map data for wireless transmission directly to in-vehicle navigation systems, personal navigation devices and mobile phones. The system is available in a growing number of cities in North America and Europe and for long haul international truck navigation, for example in Argentina, Brazil and Chile. It delivers detailed information about current traffic conditions, based on data sources such as GPS probe data from consumer devices.

Map-makers draw on information from a wide range of third party sources for their databases. Their aim is to provide information that is relevant to all types of user. Recent years have seen the development of a method of gathering this detail with the passive help of the community of map users themselves. It works by exploiting the opportunities provided by the connected vehicle for automatic reporting of errors in the map database. Details detected by GPS measurements such as one-way traffic flow, the changes in the layout of a roundabout, road gradient measurements and new road geometry can all be captured in this way.

Mapping could be extended in various ways to include road information useful to the operation of the vehicle, notably:

- static information about the roadway, such as contours, road and traffic signs, height and weight restrictions, fixed speed limits, environmental indicators (e.g. Low Emission Zones, quiet zones);
- variable information about road conditions, such as temporary road closures and diversions, "*virtual*" Variable Message Signs, weather conditions, variable speed limits, road surface data; and
- other journey-based applications, such as location, local communication with other travellers (where are my friends?), tourism information and advertising of local services.

These features can be incorporated in digital maps today but a significant improvement in the accuracy of satellite-based positioning technology is expected in the next few years.. To take full advantage there will need to be a corresponding improvement in the accuracy and detail recorded in map databases.



An important concept is the Local Dynamic Map which holds spatial data in real-time for a small area, like a road intersection or roundabout. Each intersection has a roadside station that holds the local map database and stores dynamic information on traffic and movements in the immediate vicinity, constantly updated in real-time. The roadside stations are an add-on to existing traffic control technology. Research is evaluating how the Local Dynamic Map can be used as a platform for collision avoidance applications using always-on communications with vehicles.

These significant developments point to the need for a four-way partnership between the map-makers, telecommunications companies, vehicle manufacturers and road operators to develop the connected vehicle to its full potential. Digital mapping and information services have already introduced systems with dynamic traffic data using information from other road users. Commercial arrangements with telecommunications companies will mean that communication charges are covered by a one off payment. In addition, portable units could have capability for incorporating DSRC into which would provide a platform for vehicle-infrastructure communications.

EQUIPMENT AND CONTROL SYSTEM SUPPLIERS

The manufacturers and suppliers of traffic control systems and equipment are an important commercial group. These companies are central to the development of Urban Traffic Control (UTC), controlled motorways, electronic toll and congestion charges, speed enforcement and other traffic control systems. They are involved in equipping and maintaining the traffic control centres and may train and provide the operational staff for these centres.

Traffic control technology needs to be reliable in all weather conditions, in all traffic conditions and on a 24/7 basis. The companies are actively involved in research and standards development work and require a stable operating environment in order to develop new equipment. Important design considerations are the need to maintain safety on the road at all times and prevent catastrophic failure. Systems need to be fail-safe, robust against vandalism and secure from malicious tampering.

Wireless equipment suppliers are an important sector of the market with established products for electronic payment and tolling. Their business stands to expand greatly if DSRC beacons are adopted as the accepted basis for vehicle-vehicle and vehicle-infrastructure communications and are rolled out across the road network. The companies have developed and demonstrated prototypes and are awaiting agreement on stable international standards. A few technical issues remain to be solved, for example to test the performance of these systems when scaled up to communicate with large numbers of vehicles in heavy traffic. Current work by the USA through the connected vehicle safety pilot and model deployment will hasten these developments. The latest policy roadmap for the connected vehicle program for V2V states that the "*NHTSA has committed to conducting the evaluation for making a regulatory decision on vehicle communications in 2013*".

Suppliers are taking part in demonstration schemes involving connected vehicles and co-operative systems because their products, notably UTC systems, will need redesigning to take advantage of interaction at traffic signals and probe data. Given the huge installed base of older traffic signal controllers in towns and cities world-wide there will be a sizeable business opportunity if authorities demand new or upgraded controllers with these new features.

SUMMARY

The commercial business perspective is focused on commercial opportunities, new products and services, revenue streams and a quick return on investment. A business case already exists for the development of viable services in a number of areas, using the current level of connected vehicle technology:

- Consumer applications and “*infotainment*”;
- Freight management applications;
- Charging and payment applications;
- Personal applications and social networking; and
- Navigation, journey planning and location-related applications.

From the perspective of the automotive industry there are significant technical, commercial and political risks that have to be managed. The way forward for industry is to continue, as now, making use of proven existing communication technologies, collaborating in field trials and operational tests and developing applications that bring added value to their customers. Criteria for major investment are:

- A convincing plan for investment in and operation of the infrastructure needed for a V2V security network as part of co-operative systems;
- Confidence that infrastructure-sourced data will be well managed and bring added value;
- A legal and regulatory framework that covers the deployment of co-operative systems;
- Clear market opportunities and transparency in the political, regulatory and competitive environment;
- Partnership agreements and leadership among the partners; and
- Well-developed plans for customer support and back office arrangements.

For telecommunications companies the connected vehicle is more than just another consumer device. It is a completely new user environment where services fit in, which brings together the home, the car, business and the mobile internet. New business models that make use of the smartphone and smartphone applications are emerging. The taxonomy for connected vehicle services will need to distinguish between those that are consumer market-based (value-added), automotive-based, communications-based, taxation based, or infrastructure-based. At the moment it seems unlikely that telecommunications companies will provide the ground infrastructure associated with DSRC.

THE PUBLIC SECTOR PERSPECTIVE

BACKGROUND

Public policy objectives for most countries are driven by the need to maintain or improve mobility of people and goods to support businesses and encourage economic growth. Generally economic growth is linked to a growth in traffic volumes and corresponding growth in congestion. There is a requirement to manage the impact of these increased traffic volumes so that congestion does not undermine the benefits of growth and traffic does not damage the quality of life of those living close to the road network.

Advanced economies have invested heavily in sophisticated traffic management for the urban and inter-urban road networks with Urban Traffic Control (UTC) systems, motorway control systems, softened infrastructure and road safety design along with sophisticated driver licensing and road user education systems. The vehicle fleets of more advanced nations are modern and regularly updated. It follows that these nations are well placed to benefit from the development of vehicle connectivity and will be encouraged to do so by an ageing infrastructure with constraints on its development. There is a focus on environmental improvement and carbon emission reduction. The transition to an intelligent connected vehicle is no longer a matter of decades; it can be made in years.

The situation in the less advanced economies is different. There is a focus on improving the infrastructure but greater benefit is available from improving standards of road engineering and education rather than investing in technologies benefiting only a wealthy few. However many of these nations are also investing in high quality road infrastructures financed from free flow tolling. They have embraced wireless telephone technology for mobile phones and have a strong installed commercial data and internet service. Is it possible that these countries can use these services to deliver connected technology and save some of the cost of investing in traditional traffic management, signing and safety infrastructure?

THE ECONOMIC CASE FOR INVESTMENT

Most governments face issues of increased levels of vehicle ownership and usage. Investment in new highways and improvements to the existing road infrastructure is part of a modern economy. But new roads take time to build, there is often opposition and it can be difficult for governments to keep pace. Everywhere as traffic volumes grow congestion becomes more widespread, traffic noise and air pollution levels become more serious and collisions increase in number. In the less developed world governments often face additional pressures concerning people's lack of mobility, especially in rural areas, and poor levels of security (crime) affecting the transport of goods. The social political and legal issues that road networks face are diverse and can vary greatly not only from country to country but also on a regional scale.

Some issues may be universal or apply to more than one region or country but they often differ in importance. This makes it difficult to provide generic solutions, which means that there can be different priorities regarding the use of co-operative systems in different regions. There are many examples to demonstrate the disparate nature of priorities in different countries:

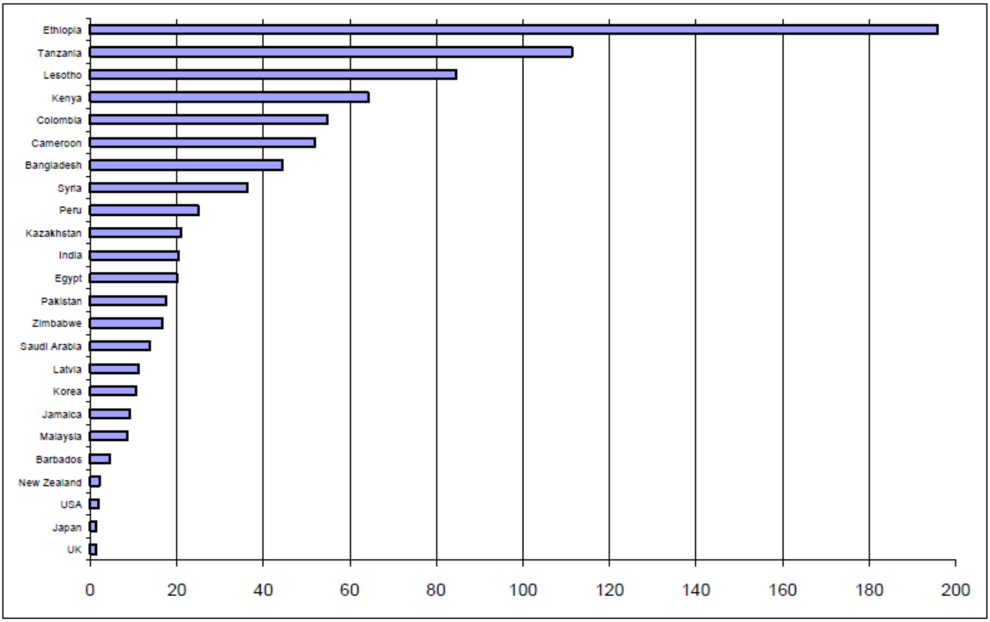
- for the US and Canada, security at border crossings is extremely important;
- the long distances covered by road networks in Australia result in issues that do not affect smaller countries;
- Europe suffers from traffic problems requiring alternative routing and therefore the priority is to make the best use of limited road capacity and encourage alternative modes;
- Africa has a large number of older vehicles and poor road quality;
- in some countries, Sweden and the Netherlands in particular, safety is the over-riding priority.

Road safety is a common thread to public policy decisions. Many governments now set road safety targets as a means of focusing attention on the measures needed to prevent road accidents happening. For example, in 2000 the UK set a target of a 40% reduction in the numbers killed and seriously injured over the following 10 years. The next generation of targets, such as the vision of zero accidents which Sweden has adopted, will be even more of a challenge. Almost inevitably they will require active safety systems which use mobile connectivity and co-operative systems.

Safety is high on the political agenda particularly with the recent launch of the United Nations initiative the Decade of Action for Road Safety 2011-2020. The goal is to stabilise and then reduce the forecast level of road traffic fatalities around the world by increasing activities conducted at the national, regional and global levels. One hundred governments co-sponsored the UN resolution establishing the Decade of Action, committing to work to achieve this ambitious objective through an action plan with targets for raising motorcycle helmet and car seat belt use, promoting safer road infrastructure and protecting vulnerable road users such as pedestrians and cyclists.

After safety, most countries battle with the need to maintain a good standard of mobility on roads. Efficient road transport is increasingly important to economic growth, serving the mobility needs of people and goods. Without it a modern economy would grind to a halt. Governments therefore have a close interest in the many improvements that the connected vehicle may bring, notably:

- improvements in traffic flow. Recent tests in the Netherlands show a 25% penetration of connected co-operative vehicles could give up to 30% improvement in flow on congested major highways;
- reductions in collisions, which adversely affect congestion even if there is no injury;
- improved incident response and management of traffic with less delay though better communications;
- better navigation and routing leading to more efficient routing and less wasted mileage;
- enabling of congestion charging based on precise knowledge of a vehicle's location and the prevailing traffic conditions.



Fatalities/10,000 licensed motor vehicles in selected countries. (Source: TRL)

Road freight is another area where the connected vehicle could impact. Efficient freight transport is vital to economic growth and stability, important for both developed and less-developed countries. More efficient journey planning and better freight logistics will improve commercial vehicle utilisation and keep freight on suitable roads. It will be possible to better organise truck parking and vehicle security with important local benefits. From the government's perspective the connected vehicle can support a tough regulatory environment (lorry routing, truck parking, load tracking) and contribute significantly to quality control. From the operator's perspective the connected vehicle can improve utilisation and reduce operating costs. Both parties can gain.

There are, nevertheless, a number of practical issues that will affect the willingness of governments to embark on a programme of investment. Long term planning of government programmes is problematic, particularly at times of economic difficulty with falling tax revenues. Another issue is the way government business is placed through competitively awarded contracts. By implication this means there must be choice of suppliers. When procuring systems or services Governments are, in general, obliged to work through contracts framed in terms of functional specifications and seek offers from multiple suppliers. This requirement to test the market militates against adopting an original (single-source) proprietary technology, however powerful or multi-featured it may be. Finally, there are areas of public and political concern, such as equity, privacy and security (both real and imagined) that have to be managed before government can fully endorse the new technology.

In summary, there are strong arguments in favour of governments encouraging the wide-spread deployment of connected vehicles. However, in general governments prefer to support R&D and standardisation, relying on industry to deploy and exploit new technologies. Hard evidence of safety, efficiency or environmental gains is required to set policy. There has to be a strong economic case for government action because public investment will have to compete with other public expenditures in fields such as health and education.

Research suggests that connected vehicles and co-operative systems will bring economic savings in transport and across other economic sectors along with environmental benefits, but for most countries (Japan is an exception) the evidence is not yet sufficiently compelling to justify a government investment programme. More work is required.

BENEFITS TO ROAD NETWORK OPERATIONS

Road operators and road network operations have an increasingly important part to play as traffic volumes grow and the road network itself gets more congested. The network operator may be part of a government department, an arms-length government agency, a local authority or city, or a private organisation. All of these entities are responsible in various ways for roads and traffic. Moreover, privately financed organisations can be operating roads either for government or independently of government. In general terms their objectives are to plan and provide and maintain a safe the road network which provides efficient cost-effective services for goods and passenger vehicles.

Road managers are expected to meet public expectations on journey time, journey time reliability, congestion, condition of carriageways and structures and safety. In cities air quality an important issue. Budgets for capital and revenue are critical. Investment in connected systems will have to compete on merit with investment in conventional engineering and other intelligent transport systems. If road managers are to invest in the roadside infrastructure to support connected vehicles the case has to be well made.

This case will be based around the prevention of accidents, better management and control and the reduced need for expensive infrastructure. There is evidence from research that short range communications will reduce accidents, but this is dependent upon the number of equipped vehicles. Better management can be achieved by broadcasting traffic management information and traffic signal timings. Better informed drivers should have smoother, more economical journeys which make better use of the available roadspace.

Broadcasting information in this way also provides the opportunity for a reduction in roadside equipment, signs VMS and gantries, all expensive to provide and maintain. In USA the State of Michigan estimates some $250,000 could be saved each time on structures work by using DSRC and in-vehicle signage to replace expensive electronic variable message sign- boards.

The cost of providing infrastructure support for the connected vehicle is unclear. Where applications can be implemented using available telecommunication systems (cellular and wifi) the costs are minimal and there is a mechanism in place for recovering the cost from the user. However, if a purpose designed short range wireless infrastructure is required the cost will be significant, even if installation is restricted to "*hot spots*". This cost has not yet been fully quantified by research. The technology issues are explored further in Part Three.

Road pricing and city charging systems provide an example where dedicated short range wireless infrastructures have proved highly cost effective. In many places compact gantry based systems have removed the need for extensive toll plazas, reducing capital costs, revenue costs and allowing tolling to take place in free flow. There is no technological reason that these systems should not be extended to provide driver information.

Data for road and traffic management

As traffic volumes grow, real-time data on road traffic and weather conditions, becomes essential to the operation of the network. This data consists of real time information about traffic flows and speeds at different points of the network. In many countries winter maintenance brings its own special need for data involving warnings of snow, ice, floods etc. and management of events and emergencies requires a need for specific data. Normally this data is collected from sensors and cameras at specific points on the network.

> Navigation companies responded the JTF questionnaire by suggesting that the data they derive from vehicles is sufficient for them to take on network management on behalf of the road operators had the knowledge on networks.

Similar data can be obtained from the vehicle fleet using connected technologies. The data may not be the same as the data used today and will need statistical and modelling treatment to turn it into useful information. Carefully developed the connected vehicle has the potential to provide better, cheaper information suitable for both planning and real time information applications. Connected vehicles have potential for savings in capital and revenue expenditure.

These vehicles can also provide information that is not readily available from normal sources. Applications on systems embedded in modern vehicles can store geographically referenced data about the roads on which the vehicles travels. This information may relate to road condition, noise level, vibration or discontinuity. A measure of road surface friction is available and may have value for carriageway assessment or for use in winter conditions.

Other benefits will come from a more complete understanding of user demand through data from the connected vehicle, which will enable more efficient use of the network. Prototypes are being tested for data analysis and decision support in Singapore, Germany and New Zealand, with near-term prediction (because real-time is already too late if you are still some distance away). One company claim to have achieved 85% predictive accuracy on arterials, higher on freeways. Having this information available should enable better journey planning.

The road operator is unlikely to be able to collect this type of data working alone. It will require collaboration with automotive companies and/or third party specialist organisations. Already, probe data from both vehicles and mobile phones are growing in importance and are increasingly being used by road operators, sourced from traffic information suppliers. The data supplements other forms of traffic condition monitoring, both for real-time reporting and historical analyses. This can be very cost-effective for developing countries where little investment has been made in conventional traffic monitoring equipment or for monitoring traffic movements in complex urban networks.

In some countries digital mapping companies have contracts with the authorities to supply their data on point-to-point journey times for traffic management purposes, often partnering with and a local vehicle operator to provide a core fleet of traffic probes.

SUMMARY

> Michigan DoT reported that data collection by conventional methods is labour intensive and is estimated to cost $2million annually.

Governments are concerned about the big picture: security, mobility, safer roads, greater transport efficiency, employment and job creation, sustainability and lower emissions. No public investment can happen without a strong economic case based on evidence of benefits to the economy and society.

The promoters of co-operative systems need urgently to deconstruct the benefits of the technology and sell solutions to problems, especially with the politicians: safety benefits, security benefits, economic benefits, job creation, environmental benefits, etc.

The available evidence points to a strong case for action by governments based on improvements in road safety and by road operators based on greater efficiency in maintaining and operating roads. VICS in Japan has shown that a government-led approach can lead to a significant uptake of connected systems. The Japanese system, VICS, connects through infrared beacons in urban areas as part of the police-led Universal Traffic Management System. On the freeways DSRC microwave beacons have been installed to carry travel information and for electronic toll payments.

In order to act governments need to be satisfied that the chosen road-map for deployment of co-operative systems is viable and has the backing of all the main stakeholders. The public for their part will expect guarantees on the complete reliability of co-operative systems and sound proposals for the management of risks when things go wrong. Reassurance on issues of privacy and the "*fairness*" of these systems, perhaps with legislation, will also play a big part in what will be politically acceptable.

From the perspective of the road operator, the connected vehicle and co-operative systems taken together offer a powerful new approach to managing roads and traffic. Road network operations have much to gain from the introduction of the connected vehicle. The technology can be harnessed to develop applications that will enable:

- better, cheaper information services and knowledge of network usage,
- road facilitates management, charging and access control,
- reduced delays from accidents and congestion,
- tracking of secure or hazardous loads,
- charging and tolling without delaying traffic,
- improved options for traffic management and control,
- non-invasive data capture with less damage to the infrastructure,
- travel and traffic information.

Road users demand that the network provides a reliable, predictable and safe journey. The network as a whole is shared between different authorities, often with a division between urban roads operated by city authorities and inter-urban trunk connections run by a private toll-road company or public sector highways agency. If there is an obstruction or failure action has to be taken to re-route or delay traffic and this often involves more than one jurisdiction. This division of responsibilities means that road operators must work together in concert if the full potential of connected vehicles is to be realised.

The role for DSRC infrastructure is evolving. DSRC is, at this point, a clear choice for V2V safety applications with the caveat that communications technologies are evolving quickly and new options may become available. DSRC infrastructure is one of a few options for V2V security networks, and it is unclear who might own and install such an infrastructure. The USDOT has conducted a study of the non-technical needs for the V2V security network and are continuing with work in this area. DSRC for V2I application could be incorporated into existing infrastructure such as traffic signal systems. There are many who think the need for roadside signs will never be eliminated. A study of implementation issues and options is underway in the US.

ISSUES AFFECTING DEPLOYMENT

This part of the report explores some of the issues associated with the spread of connected vehicles, the deployment of co-operative systems and the initiatives which are being taken by industry, policymakers and road operators in response. It explores the potential for leadership to expedite development, the opportunities for using regulation to develop a market for safety applications, the role of standards and highlights some of the risks associated with intervention in a free market.

TECHNOLOGICAL ISSUES

Communications technologies

Communications technologies are fundamental to these developments. In the 1990's the choice was between infra-red and the then emerging short range radio operating at 5.8 or 5.9 GHz (DSRC). Infra red proved successful in urban environments and DSRC in inter-urban. During the 2000's the debate moved into the relative merits of GSM and DSRC and as we move into the 2010's LTE emerges as a possible addition to GSM and an alternative to DSRC.

The fundamental issue in any discussion of technology is to match the requirements of the applications to the available technology. However, technical merit is not the only consideration; the communications networks must be available and affordable. 2.5 and 3G have the big advantage of being deployed and available all over the world. These deployed technologies have the capability for handling the technical demands of most mobility and commercial connected vehicle applications. There are examples of such applications being delivered by navigation suppliers and OEMs which use some sort of blend of data and voice services. The major advantage to the use of these technologies is that payment mechanisms are established and in place, even if the existing tariff environment is not ideal for the automotive environment.

Short range communications technologies, on the other hand, meet the technical requirement for V2V and V2I safety applications, but will require new infrastructure deployment. At the present time there is no "*user pays*" capability. For these systems to be deployed there needs to be bold leadership from one of the major players. This may take the form of a decision by:

- legislators (= governments) to make V2V mandatory enabling the development of complimentary V2I; or
- governments/road operators to invest in infrastructure in order to encourage the development of new safety and mobility led technology; or
- the automotive industry responding to consumer demand; or
- a combination of public and private investment.

By targeting the use of DSRC to the applications for which it is best suited, the need for extensive roadside infrastructure may be minimised. Whilst in the ideal world every road sign and traffic signal would be broadcasting its information to every passing vehicle in the practical world the service would be deployed only in highly congested areas or hot spots, thus minimising the capital and revenue costs.

This is the policy being adopted in Japan. A publicly-funded network of bespoke dedicated short-range communications (DSRC) is being undertaken at around 1,600 hot spot sites. With this investment Japan operates a mixed environment, the VICS system using infra-red beacons in urban areas, FM and DAB radio systems, 3G cellular and DSRC on expressways.

This type of hybrid system may be a compromise solution combining the rapid rollout and capability of the telecommunications operator-based system with the responsiveness of short range technologies. An example of this approach is the development of the CALM architecture by ISO TC 204 which gives access to the most suitable communication media available. There are, of course, cost and complexity implications which have still to be fully evaluated.

The USDOT (RITA) is exploring an architecture which identifies the key functions that must be performed by a core system. The core system architecture provides for the use of the type of communication technology that meets the needs of a particular application. Operating this way DSRC would only be considered for those applications for which it is uniquely suited. This ability to mix and match applications with their appropriate communications technology is a key feature.

Radio frequency allocations

In the USA 75 MHz of spectrum within the band 5850-5925 MHz have been allocated to Dedicated Short Range Communications (DSRC) providing ITS applications with specific channels for safety and with general access priority to safety applications in all the band.

In Europe the policy is to harmonise the use of the 5.875-5.925 GHz frequency band for Intelligent Transport Systems (ITS).

In Japan, the range from 5.775 GHz to 5.845 GHz had been allocated to ITS Spot services and ETC. A decision also has been made to allocate an ITS frequency in 10-MHz bands in the range from 710 to 770 MHz. These bands will be white space when analogue TV broadcasts end in July 2011. They will be used to assist with safe driving via co-operative systems that use V2I and V2V communications. Proving tests were conducted in FY 2010. The bands will be available from July 2012.

Other countries world wide are considering the 5.9 GHz band for road safety applications which may provide further global harmonisation of the use of this particular frequency range for ITS.

Standards and architecture

The operating environment in different parts of the world has many common issues but as many local differences. For example, most cities have congestion, some will have highly developed urban traffic control systems and disciplined drivers and pedestrians. Others have little control, unsophisticated vehicles and a lack of respect for regulation. A student delegate at a workshop in Malaysia observed "if a person in Malaysia can afford a high end BMW or Mercedes they can also afford a driver. The applications they need are business applications to allow them to carry on working from the back of the car". Different solutions are required in different regions.

These differences do not mean that world standards are not very desirable. Global harmonisation enhances economies of scale in equipment manufacture and would result in wider cross-border mobility and more competition. Delegates' seminars and workshops for the Joint Task Force made it clear that there are strong economic reasons for a global approach at the communications level, but accepted that connected vehicle applications may be very different for different regions. All agreed that international harmonisation of connected vehicle standards is an important issue and difficult issue.

If world wide standardisation is an impossible dream there needs to be, at least, a guarantee that equipment will work throughout linked geographical areas, e.g. equipment purchased in Europe must work throughout the whole European area; equipment operating in the USA should, if at all possible, continue to work in Canada and Mexico. There are some applications, for example traffic signal and intersection control, which require high involvement from the infrastructure and standardisation is vital.

Significant progress has been made. Within Europe the Framework programmes of the European Commission have led the development of the technical and scientific background for European Standardisation. These results are being transferred to the

ETSI and CEN standardisation process with the aim of providing wider technical standards and specifications.

In the US standards for co-operative systems have been developed as part of the ITS Standards Program. The current standards for connectivity include the IEEE 802.11p, 1609.x and the SAE J2735 standards that primarily support the V2V and V2I wireless interfaces. These standards allow establishment of a wireless link for V2V and V2I communications (IEEE 802.11p), establish protocols for information exchange across the wireless link (IEEE 1609.x), and define message content for communicating specific information to and from equipment and devices via DSRC or other means (SAE J2735).

In November 2009 the USDOT and the European Commission Directorate General for Information Society and Media (DG INFSO) signed the European Union-US (EU-US) Joint Declaration of Intent on Research Co-operation[19]. As part of the declaration, the USDOT and the DG INFSO set a goal to support, wherever possible, global open standards in order to ensure interoperability of co-operative systems world-wide and to preclude the development and adoption of redundant standards. The Japan MLIT has since agreed to collaborate in these efforts[20].

GOVERNMENT-LED ACTIVITIES

These systems can be progressed by collaborations between industry and policymakers or by government taking on a leadership role. Either way commitment to the vision of safer, more efficient road transport is critical. Those parties who hold this vision and are committed to it must make sure that governments, the media and the public understand the benefits all can achieve from the deployment of technology.

A government lead can take different forms. In Japan the government sponsors deployment and the development of industry partnerships. In Europe the focus is in the research and development programme. In the US the Federal government is assuming a leadership role in connected vehicle systems research which is being conducted in full partnership with the automotive industry. Additionally, USDOT is researching regulatory issues and is working with US road operators to ensure full engagement with their interests and needs[21]. This three part group – USDOT, automotive industry and road operators – has been actively working and meeting together for a decade or more. The USDOT has an operational test-bed in Michigan that is networked with test-beds sponsored by State DOTs in California, Florida, Michigan, New York and elsewhere.

[19] *http://ec.europa.eu/information_society/activities/esafety/doc/library/us/joint_decl_on_coop_systems.pdf*

[20] *http://www.icarsupport.eu/standardisation/international-co-operation/us-japan-co-operation/*

[21] *http://www.its.dot.gov/connected_vehicle/connected_vehicle_policy.htm*

Demonstrations and field tests

In Japan, in 2008, the relevant government bodies, private companies, and organisations held proving tests of safe driving systems co-operate with infrastructure on expressways and ordinary roads in areas such as Tokyo. The objective of these demonstrations was to validate and publicise the systems by using V2I and V2V communications on real roads.

The USDOT in partnership with the automotive industry represented by CAMP are conducting a large-scale model deployment and safety pilot. The model deployment will include 3,000 vehicles in a single area of which 64 will be heavily instrumented with V2V technology and technology to capture driver reactions. The main purpose of the safety pilot is to capture data from ordinary drivers that will provide the basis for a 2013 NHTSA agency decision that may include regulation. Additionally, six driver clinics will be hosted around the US which will give people the opportunity to experience the V2V equipped vehicles and their safety potential.

The business case and technical road map has been explored in other operational projects. In Europe CVIS and Pre-DRIVE C2X laid the foundations for a significant study of the business benefits in the DRIVE C2X project, which promises to carry out field operational tests in seven test sites. The results of this project will be available towards the end of 2013.

Other tests are envisioned in the future for mobility and environmental connected vehicle applications. Concepts of operation are currently under development for these types of applications.

OPERATIONAL ISSUES

System security and integrity

Systems that rely on spatial and temporal information are reliant on high integrity data. The temptation for some individuals to listen to vehicle communications or interfere destructively will be great. Development of co-operative systems needs to proceed on the assumption that inevitably the system will be subject to malicious interference. As an example, consider the implications of a hacker intervening in a dialogue between traffic signal and vehicle, or interfering with the vehicle’s CANbus. A very good firewall is required if nomadic devices can connect with the vehicle CANbus.

Research carried out for the USDOT indicates that V2V will require a security system with infrastructure support that will manage certificates. These units would provide a facility issuing certificates and for store and forward of data. The communications type and amount of infrastructure is still under study as there are a few options available, each with unique issues. V2I applications may be able to function with spot infrastructure based on the need at that site. These issues are currently being studied by road operators in the US in co-ordination with the USDOT and automotive manufacturers.

Confidence is critical. Interference and a failure in security, either during trials or pilot schemes or during the early phases of roll out, would seriously damage commercial prospects. Security solutions have to be built in to the system architecture, requiring both vehicles and roadside devices to maintain firewalls.

Performance and reliability

The development and deployment of these systems has to be managed carefully to avoid the risk of early failure, disrepute and loss of confidence. Before consideration of any widespread deployment systems have to be secure, robust and reliable. This implies careful design. There must be redundancy built in to hardware design and communications so that failure of any combination of components is not catastrophic. There is an over-riding requirement to maintain safety on the road at all times, in every combination of traffic and weather conditions; and to do this for all road-users, including cyclists, pedestrians and other vulnerable road users and for all personnel who have to work on the roadway. In extremis the operator may be held liable for any safety failures. This means that a road operator working in collaboration with a third party service provider will insist on limiting liability wherever possible. Conditions would be attached, such as:

- third party equipment must be capable of being installed and maintained with the minimum of disruption to traffic and without undue risk to the safety of operatives;
- in-vehicle displays such as "*Virtual VMS*" or duplicates of signs at the roadside must conform to the legal requirements and not be in conflict;
- a third-party's systems must be compatible with the road operator's own control systems without compromising them in any way.

Systems have to be reliable but equipment failure is not the only issue. It is most unlikely that wireless communications systems will ever be totally comprehensive. There will always be places where communications systems will not operate and it is essential that drivers are aware of the status of safety systems so they know when they can and cannot rely on them.

There are other concerns about the risk of drivers becoming overly dependent on communications and "*intelligence*" for their safety. The advent of satellite navigation systems has already demonstrated that drivers are willing to sacrifice their knowledge of journeys and map to the navigation system and there are numerous examples of drivers ending up in difficulty. If drivers have traffic signal, lane keeping and hazard warning systems will they cease to concentrate? Careful design is required to ensure drivers remain alert.

Consideration has to be given to the driver interface to ensure that it does not distract or lead to complacency. Subsequent ownership of equipped vehicles will mean that adequate education and training in the use of these new systems and services will be required to promote correct use. This implies that training modes be included within the vehicle display rather than relying on accompanying handbooks. System deterioration and component failure also need to be addressed and the driver informed of the operational status of the equipment and services. It is particularly important that poor quality aftermarket equipment is not allowed to degrade the performance of "*standard*" equipment.

Further consideration needs to be given to lifetime maintenance and upgrading of communications equipment. There is likely to be a requirement for considerable training for the service industry and specialists in the maintenance and debugging of communications equipment.

Data control and data management

There appears to be a general acceptance that the provision of mobility and entertainment information is a business for the private sector (e.g. IT and navigation companies) whereas the provision of safety-related information is the domain of the road operator.

The boundary between the two types of information is by no means clear. For example, as the linkage with vehicle systems increases, mobility and mapping information has to be accurate to ensure safe and efficient vehicle operation. A misplaced road or junction on a digital map could create a hazard. In order to obtain the best overall safety results all types of information dissemination need to be combined so that vehicles receive long range warnings of safety issues combined with data from strategic and mobility sources and immediate urgent information through local channels.

The availability of reliable data from roads which have not been instrumented provides attractive opportunities for road operators to gain better insight into network performance and to facilitate greater co-operation between individual road network operators. This provides considerable potential for shared services, economies of scale and wider sociality benefits.

It is rare for local, regional and city roads to be managed as a single entity. In most cases there is a mixture of central government managing strategic roads, local authorities managing regional and local roads with cities managing urban systems. By combining geographic areas and jurisdictional responsibilities the number of agreements with third party data owners will be reduced and operational management efficiency improved. There is further complexity where private sector organisations are involved in managing inter-urban or city roads either on behalf of government caused by the different finance models.

This complexity extends into the information environment. Data are collected by various parties for both planning and management purposes. Data owned by road authorities is seen to be of value to all parties involved. Information such as roadworks plans, traffic signal plans in cities and data relating to traffic speed, volume and capacity could be shared to improve traffic efficiency, manage traffic related to events and also improve management of road incidents. However, authorities will need to be pro-active to make these data freely available.

Other information is available from a number of sources each of which may have different accuracy, reliability and timeliness components. There is also a growing informal information network based on new technology and services such as Twitter, which points to the value of the vehicle and road users as sources of data.

Third party organisations also require information for their services. Applications developers, navigation companies and even OEMS have an interest in information based services. Some service companies already use data from reliable sources (such as trucks and buses), observers and government/road operator data to produce saleable information. There may be copyright issues associated with the use of data and images from public or private networks.

LEGAL AND REGULATORY ISSUES

Regulation by law or by standardisation offers a mechanism for ensuring the take up of technologies which may benefit the entire community but also may impose a cost or mobility restriction. For example the European Commission Mandate M/453 invites the European Standardisation Organisations (ESOs) to prepare a coherent set of standards, technical specifications and technical reports within a specified timescale. A new legal framework (Directive 2010/40/EU) will assist the deployment of interoperable Co-operative Intelligent Transport Systems across Europe, linked with support for the development of European standards.

The automotive industry regards such initiatives with mixed views. There is little point in the industry investing in technological developments if regulation is to impose something different so timing is critical, regulation at the wrong time could be counter-productive and slow down developments. On the other hand the industry recognises the benefits of establishing a universal, fair market for connectivity equipment. The industry welcomes the programme of pre-regulatory, pre-competitive discussions that is now taking place.

The US research programme is providing policy support for the possibility of regulation of basic vehicle communications functions. It has identified possible timescales for regulation and established a research programme designed "*...to develop the factual evidence needed to support US Decision-making regarding a 2013 NHTSA*".

To be successful regulation has to be informed, well researched and acceptable to the public. Seat belt legislation is an example of successful regulation. It was not undertaken in a single step but through a planned evolution, thoroughly researched and presented in such a way as to overcome public objection. Countless lives have subsequently been saved.

Vienna Convention

The Vienna Convention on Road Traffic is an international treaty concerning the signing system for road traffic (road signs, traffic lights and road markings). The Convention may need updating to make allowances for the consequences of the connected vehicle. It was designed to facilitate international road traffic and to increase road safety through the adoption of uniform traffic rules. It defines a driver as "*any person who drives a motor vehicle or other vehicle (including a cycle)*". It states that every vehicle shall have a driver who has the requisite knowledge or skill to control the vehicle and that "*every driver shall at all times be able to control his vehicle*". It also sets out a hierarchy of traffic signals and signs in which signals take priority over traffic signs which in turn take priority over other instructions.

The wording of the convention has not been tested but it has implications. Systems which enhance the driver's ability to control a vehicle will comply with the convention so long as the vehicle remains under the driver's control. Under the convention it would not be possible to replace traffic signs or signals by on-board equipment, although it is acceptable to enhance their functionality with the addition of on-board equipment. The UNECE is aware of the issues and is working towards a solution.

Vehicle Type Approval and Certification

Most countries or regions mandate a set of environmental and safety standards for motor vehicles, often referred to as type approval or certification systems. The United Nations is currently attempting to standardise international Type Approval directives to a common standard, so new vehicles produced anywhere in the world can be sold anywhere in the world. Other regulatory systems are not ideal for dealing with the world vehicle or co-operative systems but are under development.

On the back of the United Nations initiative there is currently a new EU Type Approval directive being tabled - an update of the European Whole Vehicle Type Approval (EWVTA). This Directive is designed to harmonise all type approval schemes, even the local (SVA/LVTA/TUV) type tests, across Europe, so each vehicle and each component fitted to a vehicle has to be fit for purpose. By tidying up these anomalies this new directive will allow for each certificated vehicle type to be sold anywhere in the European Union, not just the country in which it was approved. It remains to be seen whether it will be possible for this framework to embrace communications based safety systems.

International standard ISO 26262 is a Functional Safety standard, currently under development, titled "*Road vehicles -- Functional safety*". This standard is an adaptation of the Functional Safety standard IEC 61508 for Automotive Electric/Electronic Systems. It provides guidance on safety aspects of the product lifecycle from development to decommissioning and risk analysis to ensure an acceptable level of safety.

Are these measures adequate to assure the quality and reliability of co-operative systems? One suggestion made was the imposition of a certification system: a framework for conformance testing and certification to ensure that interoperability standards are achieved and design standards are adequate. The scale of the certification process is a trade off between the cost of certification of data and equipment and the effect on the cost and quality of the service provided.

Liability

With current technology there are established mechanisms for establishing liability when collisions occur. However, the introduction of a layer of technology changes the equations. Were safety systems fitted? Did communications and safety systems work? Were they enabled? Did the driver override? There are implications for liability and litigation. A legal framework is required which sets out the responsibilities of drivers, equipment suppliers, equipment maintainers and telecommunication agencies.

Although the primary objective of these systems will be to reduce the risk of collisions, some collisions are inevitable. Intelligent devices on modern vehicles already contain data; more advanced connected systems will provide more data both onboard and outside the vehicle, or even on other vehicles. A more intelligent, communicating vehicle will generate and store large quantities of data, some of which may be of a private nature. The data may be of interest to the authorities, police and insurance companies. For example, the police in Britain can call on a forensic investigation vehicle to extract data relating to vehicle movements, or driver telecommunications, just before an event.

All parties cite liability as a priority issue and significant regulatory constraint to the development and implementation of co-operative systems. Liability and regulatory decisions are vital if rollout of co-operative systems is to proceed.

Privacy

When a road authority uses data obtained from a specific vehicle or targets an individual's mobile phone with traffic information the issue of privacy must be addressed. It is important for system developers, service providers, resellers of both systems and services as well as the actual users of the data to understand the terms of use, what existing laws concerning data protection are relevant and whether there are any interest groups, either public or private, who are involved in campaigns either for or against this type of data collection.

Privacy is a complicated issue. The JTF consultations exposed very different attitudes to privacy in different countries and different attitudes within those countries. Whilst some people may see privacy as an important aspect of personal freedom others are prepared to give up privacy in order to access security and financial benefit. Indeed the use of credit cards and social networking systems suggest that so long as there is some practical benefit people, especially young people, will readily surrender their privacy.

Privacy and data protection are important issues that need to be carefully considered. This is especially crucial for businesses and in countries where data protection legislation is well developed. Governments have a duty to protect the rights of individuals and privacy and data security become increasingly important when commercial services (perhaps value added services provided using the capabilities of the connected vehicle) are involved.

The USDOT has developed, with its road operator, automotive and other partners, a set of Privacy Principles. These principles have been a guiding resource in the research and design of prototype systems. The US has taken an approach of designing privacy into the V2V and V2I connected vehicle systems so that personal privacy is assured due to the design of the system, the data collected and the management of the data.

SUMMARY

People, businesses and authorities have, over many years, developed strategies for managing vehicles and journeys. Over the same period drivers have developed knowledge and skills in vehicle control, navigation and safety. When gathering opinions for this report there was agreement that connected systems have potential not only to change the way people drive, behave and manage their journeys but the way associated businesses and authorities operate.

Leadership from government and other influential organisations is required to encourage the development of connected vehicle applications and the deployment of technology based systems. This will need to be based on a strong business case and a vision of the benefits the systems can bring. Research continues to build the business case.

Governments in the developed world cannot afford to ignore safety applications. Safety and security of the roadway and traffic control systems must always be paramount. Over the last decade there were significant improvements in road safety and road fatalities in many European countries were halved. There is pressure to sustain this improvement over the next decade which will fuel the development of active safety systems, most of which demand some form of V2X communications which are secure and responsive.

Regulation has an important role. Without regulation DSRC based safety applications may not happen, or may be deferred for many years, at a cost to people's lives and quality of life. The market will deal with the deployment of infotainment and information systems but authorities have the responsibility of establishing the case for safety systems, ensuring uniform coverage and increasing the pace of adoption.

There is widespread concern that connected vehicle equipment might be brought into disrepute through issues of driver distraction. Distraction may be caused by the operation of the equipment itself, the ability to communicate with other people, panic or overload in the event of a crisis. Demonstration projects have shown that careful design, for example by monitoring driver behaviour and inhibiting function during times of activity, can reduce risk. However the uncontrolled development of applications for aftermarket devices could discredit the entire market.

It is necessary to assure policymakers and the public that systems are mature, secure and operate within a known legal framework before deployment of formal systems. There also needs to be realisation that informal systems may develop in an organic manner using commercial systems and, unmanaged, may not have an overall positive impact.

Agreement on global standards and architecture is essential. It is in the interests of all stakeholders to have as much commonality and economies of scale as possible. Deployment of these technologies carries risk. There is the risk that premature deployment may fail and bring this technology into disrepute with both policymakers and the public; there is risk that unforeseen effects may negate the safety advantages of the technology, perhaps even reducing safety standards. There is the risk that driver behaviour may change and that distraction or carelessness may undermine the benefits.

Timing is critical. The public and trader, the consumers, must be receptive and educated. A legislative framework must be in place. The technology used must be mature, in place and reliable. Deployment at the wrong time will set back the development of co-operative systems by years.

WHERE NEXT?

SUMMARY

This final part brings together the main themes that have emerged from the dialogue between Joint Task Force members with road network managers, government officials, researchers and other leading players in the development of connected vehicles and co-operative systems.

Today's road network managers have to consider the overall mobility of people and goods across the various transport modes. A coherent shared view of network operations has to be developed among the operating partners in order to offer an integrated approach. Co-operation includes exchange of information on road availability, recommended routes, mode connections, expected journey times and incidents. Different road managers have to co-operate on daily operations to be able to implement their own strategies in a coherent manner. This includes interfacing with private service operators (e.g. traffic information service providers who use probe vehicle data) and training Traffic Operation Centres staff. Last, but not least, it is important to pay better attention to user needs that evolve rapidly with the fast introduction of new mobile communication facilities, and the rapid development of social networks.

There is consensus that the intelligent connected vehicle has the potential to make travel safer, more efficient and more comfortable. It can make the fleet more reliable and reduce the overall running costs. It can also impact on government objectives by enabling Carbon reductions, reducing healthcare costs and reducing the pressure for new investments and construction. It provides an opportunity for the development of new applications and businesses. Based on the evidence available to the JTF it is clear that the connected vehicle may come in two quite different guises.

The first and easiest involves the ongoing development of applications using existing commercial wireless telecommunications to provide V2I and perhaps even V2V services. These services can come in different forms, such as enhancements to satellite navigation systems, embedded SIM cards in vehicle systems or smartphones. The development of these systems is progressing rapidly and their capability will expand with the advent of the next generation telecommunication services which will better support machine to machine connectivity. It is also clear that the next generation of drivers will have been brought up in the connected world and will expect those services to support their travel. However, at this time there is no evidence that commercial services have the technical capability, responsiveness and reliability to support the short range services necessary to obtain the maximum benefit from some safety applications.

The second approach involves the development of a new, bespoke, short-range system optimised for safety and short-range traffic control applications. The wireless technology required has been developed and tested over the last 30 years and the technological capabilities are well understood. International standards are well advanced. Deployment is dependent upon the case for investment. However, the task force has not been able to identify any commercial business model strong enough to support the deployment of the ground infrastructure necessary for widespread, secure implementation. The question is then whether the benefits to the community, economy and society are sufficient for central and local government to finance ground infrastructure deployment.

The one area in which short range wireless communications is commercially successful is electronic tolling and charging. This technology allows revenue to be collected without the disruption associated with toll booths. It is proven and widely used. It is possible for safety services or other commercial services to ride with these but so far the industry has shown a preference for keeping charging services separate.

There is, of course, an overlap between these types of applications and it is possible to consider an architecture in which vehicle and land systems make use of the most appropriate communications technology available and suitable for a particular application. This approach has been demonstrated using the CALM[22] communications architecture.

At a technical level the task force welcomes the interest and engagement of international organisations such as United Nations Economic Commission for Europe (UNECE), the Conference of European Road Directors (CEDR), the American Association of State Highway and Transportation Officials (AASHTO), the Japan Smartway Partner Council, the International Road Federation (IRF) and other established groups that are considering these issues. ITS Europe (ERTICO) has led the establishment of the Co-operative Mobility Alliance. There is agreement to international collaborations between US, Europe and Japan. There has also been much progress with international standards.

All this collaborative activity has emerged since PIARC and FISITA entered into dialogue four years ago. Collaboration at an international level is seen to be essential and the examples of collaborative working emerging within and between US, Europe and Japan are welcome developments.

Security

Systems that rely on spatial and temporal information are reliant on high integrity data. The temptation for some individuals to listen to vehicle communications or interfere destructively will be great. Therefore the development vehicle communications systems has to proceed using the assumption that the system will be subject to malicious interference. As an example, consider the implications of a hacker intervening in a dialogue between traffic signal and vehicle, or interfering with the vehicle's CANbus. Just as telecommunications companies have developed measures to protect users of commercial wireless systems, dedicated short range systems will require a certification and quality assurance system to be in place. Vehicle systems will require firewalls. There was a view that V2V may not be able to exist without being accompanied by V2I and that the architecture should include the provision of a certification system using trusted roadside units ("trust centres").

[22] http://www.isotc204wg16.org/concept

Confidence is critical. Interference and a failure in security, either during trials or pilot schemes or during the early phases of roll out, would seriously damage commercial prospects. Security solutions have to be built in to the system architecture, requiring both vehicles and roadside devices to maintain firewalls.

Legislative issues

The automotive sector has concerns about the consequences of a failure in design. It looks to governments to provide a legal and regulatory framework that covers the deployment of co-operative systems. There is a presumption that most applications, even safety-related applications, will assist the driver rather than take over any control functions and that, providing system design is carefully considered, liability need not be the difficult issue that some have made it out to be. This has not been tested in law.

Privacy

The consultations showed a diverse set of opinions and requirements for privacy. There are some sectors of the market which resist any intrusion into privacy. There are seen to be issues of personal security, financial security and personal freedom. There are also market sectors which perceive advantages to loss of privacy through, for example, cheaper insurance or even, in the case of the young, feasible insurance. The younger generation seemed less concerned about loss of privacy.

THE WAY FORWARD

The commercial sector

The commercial business perspective is focused on commercial opportunities, new products and services, revenue streams and a quick return on investment. A business case already exists for the development of viable services in a number of areas, using the current level of connected vehicle technology:

- consumer applications and "*infotainment*";
- freight management applications;
- charging and payment applications;
- personal applications and social networking; and
- navigation, journey planning and location-related applications.

The digital mapping and information services sector is making a strong showing in these areas. The leading companies are equipped to provide their customers with OEM and after-market equipment and follow up services using, for example, Radio Data System data or the commercial cellular telephone network. These companies now have sophisticated databases containing data about the road network. Initially set up using survey work these databases are updated using data from user vehicles and can provide a mix of static and dynamic information. The companies argue that they are able to provide their users with information services which could replace those provided by most road operators and that they could provide a new business model for the operation of road networks.

The automotive industry

From the perspective of the automotive industry there are significant technical, commercial and political risks that have to be managed. The way forward for industry is to continue, as now, making use of proven existing communication technologies, collaborating in field trials and operational tests and developing new business models and applications that bring added-value to their customers. Criteria for major investment are:

- a convincing plan from government and road operators for investment in the infrastructure-side of co-operative systems;
- confidence that infrastructure-sourced data will be well managed and bring added value;
- a legal and regulatory framework that covers the deployment of co-operative systems;
- clear market opportunities and transparency in the political, regulatory and competitive environment;
- partnership agreements and leadership among the partners; and
- well-developed plans for customer support and back office arrangements.

Telecommunications companies

For telecommunications companies the connected vehicle is more than just another consumer device. It is a completely new user environment where services fit in, which brings together the home, the car, business and the mobile internet. New business models that make use of the smartphone and smartphone applications are emerging. The taxonomy for connected vehicle services will need to distinguish between those applications that are consumer market-based (value-added), automotive-based, communications-based, taxation based, or infrastructure-based.

The public sector

The case for action by governments will need to rely on improvements in road safety and by road operators based on greater efficiency in maintaining and operating roads. In order to act governments need to be satisfied that:

- the promoters of co- operative systems can deconstruct the benefits of the technology and sell solutions to problems, especially with the politicians: safety benefits, security benefits, economic benefits, job creation, environmental benefits, etc.
- the chosen road-map for deployment of co-operative systems is stable, viable and has the backing of all the main stakeholders.
- the technology will yield the safety benefits predicted.

- the issues of security, liability and risk can be managed.
- viable operational partnerships can be established between the telecommunications, automotive, digital mapping and information services sectors.

The public for their part will expect guarantees on the complete reliability of co-operative systems and sound proposals for the management of risks when things go wrong. Reassurance on issues of privacy and the "*fairness*" of these systems, perhaps with legislation, will also play a big part in what will be politically acceptable.

Road operations

The case for investing in the connected vehicle and co-operative systems from a road network operations perspective will concern safety benefits, improvement in operations and fewer traffic law violations. Developments that will enable flexibility in road pricing, emissions monitoring, and crash avoidance will also be welcome.

Vehicle to infrastructure communication necessitates investment. No satisfactory business model has been found up to now that will allow the private sector to invest independently of the public sector. There are likely to be significant social benefits in terms of safety, energy saving that call for public investment, but so far there has been insufficient demonstration of such benefits, and authorities are reluctant to make the first step. Co-operation between road authorities and automotive industry should be pursued, certainly extended to road industry (road design and equipment) and telecom operators/OEM industry.

Co-operation in the future will extend to the vehicle itself. Road vehicles – buses, trucks and cars – are already contributing more and more to the transport system, thanks to real-time communication between vehicle and service providers. This will develop in the future, with the extension of data exchange between vehicle and infrastructure. But the full potential of this technology in support of road safety, mobility and environmental policy goals can only be realised if some basic conditions are fulfilled.

A subject of vital importance to road managers is the possibility of improving the way they can maintain and operate their roads using the knowledge and feedback available from the user fleet, in particular to monitor regularly road network conditions and check if performance objectives are reached. Road users have come to expect a good level of service: high levels of safety, reliable traffic information, dependable journey times, rapid incident response and, so far as possible, all-weather operations. These benefits cannot be fully realised unless Road Managers are willing to consider new ways of working, new types of data and even new organisational structures.

The evidence given to the task force has confirmed that the vehicle has the capability of gathering, storing and returning useful data on traffic and road conditions. Can data from a vehicle be used to create a continuous description of road and traffic conditions which will improve operational practice? Can the use of vehicle data contribute to mobility management for people and cars in urban areas; to the reducing carbon emissions and greenhouse gases from road transport; and to the task of improving road network operations in general? These are important issues which demand the attention of highway and automotive engineers. They need to work together to develop the methodology, in close collaboration with private sector map-makers and data providers.

FOLLOW UP WORK

The development of a market for intelligent co-operative systems requires close relationships between all sides of industry. The commercial sector may be able to satisfy the needs of their customers by working in isolation but there are wider opportunities and business models being developed which involve with governments and road operators. The issues need to be debated between those in the public and private sectors who will be most closely involved in deployment to reach agreement on how to proceed. These discussions need to take place at a pre-competitive stage and concern the roadmap for development, the roles and responsibilities of the various players, investment priorities, decisions on what system architecture to adopt and the areas of standardisation that are needed. It is hoped this report will contribute to these discussions.

Many in the transport sector who are unfamiliar with the developments considered in this report will be unaware of the implications for road transport of the connected vehicle and the potential that co-operative systems have for advancing safety, efficiency and environmental targets. There is a need to engage with a wider audience of professionals and policy-makers, e.g. through the International Transport Forum or the International Bridge, Tunnel and Turnpike Association (IBTTA).

Instrumented vehicles will provide a platform for acquiring data in real-time at low cost across all classes of road, covering not only congestion and travel times, but also trip origins, destinations micro-climate, skid resistance and pavement condition. The statistical methods used to derive useful information from vehicle data will have to be developed to specifications which can enhance or replace traditional ways of working. PIARC and FISITA are well placed to work together on this important subject, by identifying opportunities for collaboration, specifying needs and requirements and sharing emerging good practice.

From the perspective of the road manager, there remains a requirement for continuous monitoring of the results of field trials and consideration of the issues as they continue to develop. For example the use of vehicle data for traffic monitoring requires further work. There is a need to develop further understanding of the implications of the connected vehicle and to provide impartial education and information so that key investment and deployment strategies can be developed.

In conclusion the development of the connected vehicle is moving ahead rapidly. The immediate focus is on applications which make use of exiting commercial telecommunications services and there is continuing research to develop safety-related services that are reliable and secure. This work is moving forward in a collaborative way on a regional basis with an increasing awareness of the global issues informed by international collaborations.

***

GLOSSARY (English)

Term	Definition
1-2-M	One to many
3G, 4G	3rd , 4th Generation digital cellular communications
ANPR	Automatic Number-plate Reading
ATIS	Advanced Traveller Information System
BRT	Bus Rapid Transit
CALM	Communication Access for Land Mobiles (wireless communication protocols)
CAMP	Crash Avoidance Metrics Partnership (USA)
CANbus	Controller Area Network
CCTV	Closed-circuit television
CEN	Comité Européen de Normalisation (European Committee for Standardization)
D2V	Device to vehicle
DAB	Digital Audio Broadcasting (digital radio)
DSRC	Dedicated Short-Range Communications
eCall	Automatic vehicle crash notification
ETSI	European Telecommunications Standards Institute
EWVTA	European Whole vehicle Type Approval
GHz	GigaHertz (ultra high frequency microwaves at 1 billion cycles per second)
GPS	Global Positioning System
GSM	Global System for Mobile communications
HMI	Human Machine Interface
IEEE	Institute of Electrical and Electronics Engineers (USA)
ISO	International Standards Organisation
IT	Information Technology
ITS	Intelligent Transport Systems
IVHS	Intelligent Vehicle-Highway Systems
LTE	Long-Term Evolution (of UTMS technology)
LVTA	Low Volume (vehicle) Type Approval
OEM	Original Equipment Manufacturer
SAE	Society of Automotive Engineers (USA)
SPaT	Signal Phase and Timing (traffic signals)
SVA	Single Vehicle (Type) Approval
TUV	Vehicle Type Approval (Germany)
UTC	Urban Traffic Control
UTMS	Universal Mobile Telecommunications Service (3G communications standard used throughout much of the world)
V2C	Vehicle to Cloud (computing)
V2G	Vehicle to Grid (electricity)
V2I	Vehicle to Infrastructure
VICS	Vehicle-Infrastructure Communication System (Japan)
VII	Vehicle Infrastructure Integration (USA)
VMS	Variable Message Sign