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ROAD NETWORK OPERATIONS & INTELLIGENT TRANSPORT SYSTEMS

NETWORK CONTROL

ROAD SAFETY

Accident Analysis
Data Capture
Black Spots
Speed Management
Intelligent Speed Adaptation
Policing / Enforcement
Safety of Vulnerable Road Users
Information / Warning
New Applications

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ROAD SAFETY

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Across the world 1.24 million people lose their lives each year on the roads. A further 20-50 million suffer non-fatal injuries. The United Nations (UN) Decade of Action for Road Safety (2011-2020) aims to halve annual road fatalities by 2020, compared to 2010.

Advanced Information and Communication Technologies (ICT) can contribute significantly to road safety, enabling sophisticated ITS applications to be deployed to prevent accidents, reduce their severity and improve survival rates. Road authorities are the major public stakeholders in ITS and largely responsible for their safety aspects.

Far-reaching developments include in-vehicle control systems and roadside information, traffic control and enforcement – which impact on the safety of drivers, road workers, cyclists and pedestrians, all of whom are particularly vulnerable. For example:

- pedestrians and cyclists can be detected at signalised crossings - and traffic control can be designed to reduce the risk of accidents to them. Those with impaired movement - the elderly, people with young children, and those with disabilities need special consideration (**See** Vulnerable Road Users)
- weather and road-surface conditions can lead to road accidents and incidents. Advanced weather warnings enable drivers to avoid dangerous areas. They also enable road operators to react to natural hazards such as winter ice or floods by directing equipment such as snow ploughs to the most severely-affected areas and, if necessary, prioritise evacuation and emergency vehicle access routes (**See** Weather Management)

Many ITS systems have been developed with the primary aim of increasing road safety – such as improved vehicle control in critical situations and automatic alerts for assistance after an incident has occurred. (**See** Driver Support)

The following systems are already implemented by many road authorities:

- speed control systems (local danger warning, variable speed limit signs)
- Intelligent Speed Adaptation (ISA)/speed alert (integrated with interoperable digital speed limit databases)
- automated enforcement of traffic rules (red light cameras, speed enforcement, distance control in tunnels, alcohol locks)
- incident management (automated incident detection)
- Variable Massage Signs (VMS) designed for speed control
- in-vehicle or infrastructure based warning systems (e-Call)

Other systems, for which safety was not the primary motivation, will nevertheless affect safety because their use results in changes in travel and driving behaviour – for example travel information systems giving forward warning of an accident ahead may prevent the occurrence of secondary collisions.

Systems aimed at improving safety generally have a positive influence on drivers and road users - but they can also have a negative impact – for example through behavioural adaptation or risk compensation. (**See** Human Factors)

World Health Organisation (WHO)
Global Status Report on Road Safety 2013

The WHO report presents road safety information from 182 countries across the world, accounting for 99% of its population. It provides the baseline for the UN Decade of Action for Road Safety 2011-2020. Traffic injuries are the eighth leading cause of death globally, and for young people (aged 15-29) they are the leading cause of death. At the national level, road traffic injuries result in significant financial costs - particularly for developing economies. The costs to low-and-middle-income countries is estimated at being between 1–2 % of their gross national product - over US$ 100 billion a year.

Unless urgent action is taken, WHO suggests that by 2030 road traffic deaths will become the fifth leading cause of death. Currently only 28 countries, covering 7% of the world's population, have comprehensive road safety laws for five key risk factors: drinking and driving, speeding, and failing to use motorcycle helmets, seat-belts and child restraints. Over a quarter of the fatalities are among pedestrians and cyclists – but to date, these road users have been neglected in transport and planning policy.

REFERENCE SOURCES

World Health Organisation (2013) ***Global Status Report on Road Safety 2013: Supporting a Decade of Action*** ISBN 978 92 4
1564564, http://www.who.int/violence_injury_prevention/road_safety_status/2013/report/en/

PIARC Technical Committee 3.1 Road Safety (2011) *T**aking Advantage of Intelligent Transport Systems to Improve Road Safety*** ISBN 2-84060-233-4 http://www.piarc.org

ACCIDENT ANALYSIS

Reduction in accidents, and in particular injury and fatal accidents, is a primary focus of many ITS deployments. Integral to these is an understanding of how the existing traffic situation (driver behaviour, vehicle dynamics and road environment) relate to safety. Also key is understanding that an ITS scheme which is not in itself targeted specifically at road safety – may nevertheless result in changes in the level of safety as an unintended side effect.

Deployment of ITS can alter the balance of accident types. It is not uncommon with traffic schemes for one type of incident to be substantially reduced and another type to increase (perhaps of lower severity). In general, ITS deployments that reduce congestion and smooth traffic flows will reduce accidents. High variability in speeds — of the vehicle (rapid deceleration or acceleration) and between vehicles — is more likely to cause disturbances and incidents than steady vehicle speeds. In general higher overall speeds will increase both accident risk and severity.

Accident analysis is a major tool in obtaining an understanding of the existing situation and how it could be improved by ITS. It helps to provide an understanding of the most effective solutions and is essential for monitoring and evaluating the safety of the road network. It should be undertaken, following deployment of a system, to:

- confirm that there are no unexpected negative side effects of deployment
- evaluate the safety outcome of system deployment

Monitoring is used to verify that, after deployment, the system has produced the desired effects and there are no unexpected negative side-effects. An example might be the case of a VMS, where incidents could occur as a result of drivers slowing down - in order to read the VMS or to give themselves more time for decision-making after passing the VMS.

Evaluation compares the before and after situation - ideally also comparing it with a control road or location in which there has been no intervention. This provides reassurance that an observed improvement was not simply the result of an overall trend such as a general improvement in safety performance. A rigorous evaluation will require a statistically significant change in the number of accidents to demonstrate that the change observed is not the result of chance. (**See** Evaluation)

ITS systems themselves can provide data to enhance accident analysis. The systems can notify the emergency services and traffic management centre directly that an accident has taken place – for example via eCall, for which the in-vehicle technology is mandated in new European cars from 2018. (**See** Driver Support)

More generally, the data that is available from in-vehicle data recorders and roadside systems can be used to enhance accident analysis. Accident data could include information on traffic flow, weather conditions or the status of real-time traffic management systems. For some accidents, relevant information may be captured on roadside video.

ITS has also improved data collection at the accident scene through providing sophisticated mobile hardware which is capable of:

- pinpointing the location of the collision
- capturing digital images of the site
- accessing remote databases on-line for back-up information – such as car registration databases

DATA CAPTURE

ITS systems can provide a large amount of data that is relevant to accident analysis – such as data on weather and traffic conditions. Digital road maps may contain information on road horizontal curvature and slope in addition to other roadway information such as vehicle restrictions or number of lanes. In-vehicle data recording provides an additional source of information. Arrangements need to be put in place to archive this data for accident investigation and analysis.

DATA CAPTURE AT THE SCENE OF THE ACCIDENT

Hardware advances in recently years have also improved accident investigation and recording (see the example, CRASH, in the display box below). Similar systems include the Road Accident Data Management System (RADMS) developed by the World Bank and the Road Accident Data Recorder (RADaR) developed by the International Road Federation.

CRASH – Collision Recording and Sharing (UK)

The CRASH electronic system used by police forces in England and Wales for data capture at the scene of collision combines digital technology with information management. It enables secure collection, validation, transmission and storage of road traffic collision reports. It supports police business needs and the Department for Transport's statistical requirements.

CRASH is hosted on the Police National Computer and imports and exports data to and from other agreed agencies and their systems – such as the vehicle record at the Driver and Vehicle Licensing Agency. By providing automated access to complementary sources of information, it maximises the efficiency of police time when reporting an accident. A police officer only needs to record the vehicle's registration number – rather than other details, such as the make, model and colour of a vehicle, and the owner. Collision locations are more accurately positioned using built-in GPS receivers and interactive maps.

DATA FROM ROADSIDE SYSTEMS

Roadside systems can supply information on weather, road surface conditions and traffic flow. Video of the accident scene may be available from CCTV cameras and the Traffic Control Centre. The data can be transmitted to a national or regional Traffic Control Centre (TCC), which can then initiate appropriate action – such as dynamic speed limit management. For example, the TCC may set a temporary lower speed limit in response to adverse weather conditions or road accidents – and communicate this to the road users through a range of media, such as VMS or subscription based news/traffic channels.

Real time monitoring of traffic conditions via sensors and imaging technologies also support TCC operator awareness of unexpected events – such as road accidents and stranded vehicles – so they can take appropriate action. Video of the accident scene may be available from CCTV cameras and the Traffic Control Centre. (**See**: CCTV, Weather Monitoring, Vehicles and Roadways, and Traffic Control Centres)

Active Traffic Management (UK)

The Active Traffic Management (ATM) system in the UK consists of sensors buried in the lane to monitor traffic flow and speeds. If any abnormal patterns are detected, the TCC operator can confirm the incident by looking at CCTV images and setting the VMS systems – to show temporary speed limits or specific messages, as below. The ATM system was trialled on the M42 in 2003, fully implemented in 2006, and has gradually evolved into the current Smart Motorway system. (See Case Study)

Active Traffic Management Systems. Key: CCTV = Closed-Curcuit Television; AMS = Advanced Message Sign; ERA = Emergency Rest Area; HSR = Hard Shoulder Running; AMI = Advanced Motorway Indicator.

DATA FROM IN-VEHICLE SYSTEMS

Tachographs and fleet management systems can provide data on driver hours of service and vehicle speeds. The use of video cameras as an integral part of fleet management systems is becoming more common. The camera view may be of the forward roadway only or it may also extend to a cabin (driver) view allowing investigation of driver attention in the pre-accident period. Fleets typically use such data for feedback to drivers, driver training and investigation following an incident. The saving of data for a time window is typically automatically triggered by an accelerometer that detects rapid acceleration or deceleration.

EVENT DATA RECORDERS

So-called “blackbox” Event Data Recorders (EDRs) are mandated for other modes of transport such as civil aviation but are not yet required for road vehicles. The recorders provide enhanced quality and accuracy of accident data. Typically, they store recent data in short-term memory – and the memory store is replaced at frequent intervals. Once an event, such as airbag deployment, is detected, the data in the memory store is permanently saved. This will comprise information on the status of vehicle sensors and control systems which can be accessed from the vehicle’s Controller Area Network (CAN). Data can include information on speed, accelerator pedal position, brake activation, driver use of seatbelt, as well as use of on-board vehicle systems such as cruise control or speed limiter prior to and during an accident.

EDRs are already present in a large proportion of vehicles, including over 90% of light vehicles in the USA. There is a US standard for EDRs fitted in light vehicles (Code of Federal Regulations Title 49 part 563). It is intended to ensure that data from an accident is usable for accident investigation purposes and can assist in analysing the performance of advanced safety systems such as restraint systems. The standard specifies common requirements for EDRs in terms of vehicle information such as speed, accelerator position, brake application, engine speed and speed change through a collision. It also requires vehicle manufacturers to provide data retrieval tools. There has been extensive discussion, particularly in North America, about mandating the fitting of EDRs in all new light vehicles - but to date, no legislation has been enacted. (**See** Probe Data)

ADVICE TO PRACTITIONERS

Reliable accident reporting systems have value in enhancing understanding of conflict and behavioural issues and in identifying common causes of accidents and developing effective countermeasures.

Procedures need to be put in place to store and archive relevant data from roadside systems. There are privacy issues associated with data stored by fleet management systems and in-vehicle Event Data Recorders. In some countries the consent of drivers may be needed to access the EDR information unless there are legal provisions that provide s of access in certain situations. (**See** Legal and Regulatory Issues)

REFERENCE SOURCES

Information from the US National Highway Traffic Safety Administration (NHTSA) about research on event data recorders is available at http://www.nhtsa.gov/EDR.

The USA regulation on Event Data Recorders can be found at http://www.nhtsa.gov/Laws+&+Regulations/Other+Equipment.

BLACK SPOTS

Analysis of prior accident history can be used to guide decisions on the deployment of safety-related ITS systems – systems primarily targeted at reducing accident numbers and accident severity. The analysis can help identify what systems to install and where to install them. There is little benefit to road network operations from deploying systems and technologies where they are not needed - and where they will have little impact. For example in many countries the location of speed cameras is determined by considering the relationship between the number of speed violations and excessive numbers of accidents. A similar approach, focused on the relationship between accidents and violations, can be used to determine the best location for red light cameras.

High-quality accident databases and appropriate tools for data extraction and analysis are required to identify problem sites. Proper procedures need to be applied to site identification to avoid selecting sites that are not fundamentally unsafe but may be subject to random fluctuations in accident numbers from one year to another. This problem is known as “bias by selection” where the resulting observed “improvements” in performance are in large part the result of random variation (“regression-to-the-mean”).

Before deciding that an ITS solution is needed, a proper assessment needs to be made of the alternatives. Standard tools are cost benefit analysis (CBA) and cost effectiveness analysis (CEA). CBA evaluates whether the predicted monetised benefits outweigh the costs. CEA measures alternative interventions against success criteria - such as lives saved or improvement in quality-adjusted life years (QALY). The QALY measurement represents the gap between an ideal scenario where everyone lives into old age free of disease and disability and the real-life situation in the population. (**See** Project Appraisal)

Some cooperative systems, such as intersection collision avoidance systems, are particularly targeted at blackspots. (**See** New and Emerging Applications)

ADVICE TO PRACTITIONERS

There is considerable literature on problem site identification in road safety. The standard technique is to apply the Empirical Bayes (EB) method, which considers both the regression-to-the-mean effect and the expected safety performance of a particular site, based on the safety performance of similar locations.

Practitioners in developing countries need to consider the reliability and consistent quality of the available accident data. Where toll roads exist, the data may be fairly complete, in contrast to other parts of the road network. In some countries, data may be recorded where the police have relatively easy access to the accident locations but coverage may be poor elsewhere.

FURTHER INFORMATION

A useful introduction to the Empirical Bayes (EB) method is provided by Hauer, Harwood, Council and Griffith (2002), Estimating Safety by the Empirical Bayes Method: A Tutorial, ***Transportation Research Record 1784***. A preprint version of this paper can be found at http://ezrahauer.files.wordpress.com/2012/08/trbpaper.pdf.

REFERENCE SOURCES

United Nations Road Safety Collaboration (2010) ***Manual on Data Systems for Road Safety*** can be found at http://www.who.int/roadsafety/projects/manuals/data/en/. Monitoring of interventions is discussed

in section 4.1 and evaluation in section 4.4.

Information on Quality Adjusted Life Years: European Transport Safety Council (2007) ***Social and Economic Consequences on Road Traffic Injury in Europe*** at: http://etsc.eu/wp-content/uploads/Social-and-economic-consequences-of-road-traffic-injury-in-Europe.pdf

Before and after studies concerning road safety black spots: Hauer, E., (1997) ***Observational Before-After Studies in Road Safety.*** Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety. Pergamon, Oxford, UK

Elvik, R., Vaa, T. (2004). ***The Handbook of Road Safety Measures***. Elsevier Science, Oxford, UK

SPEED MANAGEMENT

Excess speed (above the limit) and inappropriate speed (too fast for the conditions) are major factors in road safety. Increased vehicle speed leads to both greater accident risk and a greater likelihood that the outcome will be more severe – more likely to result in serious injury or fatality.

The so-called “power model” provides a good rule of thumb on how road traffic speed relates to accident risk and severity. The consequence of a small increase in speed is a disproportionately high number of accidents. A good approximation is that injury accidents change in relation to the average speed of road traffic. Injury accidents change with speed squared (v^2), serious injury accidents change with speed cubed (v^3) and fatal accidents change with speed to the fourth power (v^4). This means that reducing traffic speeds by even a small amount will have a large effect in reducing the severity of injuries.

The variants of the power model have been developed from data obtained from countries with comparatively safe roads. Countries with poor quality roads, vehicles with few safety features, a large proportion of two-wheelers and low levels of road user compliance with regulations - may experience a much steeper relationship between speed and accidents.

Variability and large differentials in speed cause disturbances in traffic flow and increase risk. For instance:

- large speed differences between vehicles result in them quickly closing in on each other with reduced time to impact (smaller safety margins)
- large differences in vehicle speeds on successive road sections are problematic, particularly where traffic has to slow down abruptly following a relatively straight and high-speed section of road. This highlights the importance of consistency in road design and speed management – to encourage better and more predictable driver behaviour

Speed management is defined by the OECD as “a set of measures to limit the negative effects of excessive and inappropriate speeds in the transport system.” This requires a strategic approach to the problem of speed - starting with setting appropriate speed limits for different categories and qualities of roads and putting in place a variety of measures that can be used to deliver compliance.

Speed management is generally a central part of a region’s road safety strategy because of the crucial role that speed plays in determining accident risk. Multiple stakeholders are involved, including central and regional government, road operators, the police and road authorities. (**See** Incident Response Plans)

The variety of measures used in speed management include:

- road design, including both layout and markings – such as the principle of the self-explaining road where road users can easily understand the function of the road, how they should drive and what to expect of other road users
- regulation, including rules on which categories of vehicle are permitted to use a road and what the speed limits are for particular vehicles
- driver training
- safety campaigns
- speed enforcement

ITS makes possible the use of in-vehicle systems to encourage drivers and riders to comply with speed limits and choose speeds appropriate to road conditions.

THE ROLE OF ITS IN SPEED MANAGEMENT

Intelligent Transport Systems have a significant role in delivering speed management. For certain types of application, they are crucial. For example, they make it possible to deliver:

- real-time roadside weather-related warning systems
- or controlled ("smart") motorways on which speed limits change in response to traffic flows (**See** Case Study: Active Traffic Management)

Increasingly, both weather-related systems and controlled motorways tend to be fully automated. They involve a range of ITS technologies and systems using distributed sensors to capture and send information to central traffic control centres for display on roadside information panels – as well as speed cameras for enforcement. (**See** Weather Management)

With the growth of real-time communications into nomadic devices and vehicles, we are likely to see greater delivery of information and warnings conveyed within the vehicle directly to the driver. It is already the case that many commercial satellite navigation systems and navigation applications for smartphones provide information on speed limits and can be set to warn the driver about speeding. It is in the interests of road authorities to provide suppliers of digital road maps with up-to-date information on speed limits and in particular with timely information on changes to speed limits.

ITS technologies can assist in:

- encouraging compliance using roadside graphic variable message signs to provide feedback to individual drivers on their speed
- compensating for deficiencies in road design by advising drivers to slow down at certain locations such as the approach to sharp curves
- informing drivers and riders about real-time conditions and dynamic speed limits
- encouraging compliance through camera enforcement (**See** Policing/Enforcement)

FURTHER INFORMATION

United Nations Road Safety Collaboration has produced *Speed Management: A Road Safety Manual for Decision-makers and Practitioners*. This is available on-line at http://www.who.int/roadsafety/projects/manuals/speed_manual/en/. Chapter 3 covers tools, including ITS tools such as Intelligent Speed Adaptation(**See** Intelligent Speed Adaptation).

REFERENCE SOURCES

OECD/ECMT*Speed Management* 2006 ISBN 9789282103784 (PDF) ; 9789282103777 (print) (**See** http://www.internationaltransportforum.org/Pub/pdf/06Speed.pdf)

INTELLIGENT SPEED ADAPTATION (ISA)

Intelligent Speed Adaptation (ISA), also known as Intelligent Speed Assistance, brings speed management into the vehicle. The aim of ISA is to discourage or prevent speeding by informing drivers about the speed limit for a road and warning them about excess speed. The most sophisticated systems prevent speeding by way of an electronic speed limiter. The fundamental distinction is whether they are advisory or intervening:

- advisory ISA systems typically beep at the driver when speeding over a certain threshold is detected
- intervening ISA systems typically limit speed at or just over the speed limit (although the driver can disengage the speed limiter at any time)

Advisory ISA is already on the market — it is a feature in many commercial satellite navigation systems, although it is generally for the end-user to decide whether to implement the function. Manually set speed limiters are available in many vehicle models. No vehicle manufacturer currently offers a full intervening ISA.

Fully- intervening ISA has been trialled extensively in real-world driving (so-called Field Operational Tests). These trials have produced generally positive results in terms of behaviour, showing that the use of ISA in all its forms brings about a significant reduction in speeding. They also indicate a reasonable level of acceptance by users, even though users might feel somewhat disadvantaged by having ISA in that they can see other drivers travelling faster than they are.

Using well-validated models of the relationship between driving speeds and risk - calculations of the impact of ISA on accidents have been made. Probably the most comprehensive set of calculations is from trials conducted in the ISA-UK project during 2004-2006. The prediction is that an advisory ISA in general use, would save 3% of injury accidents and an intervening ISA would save 12% of injury accidents and 20% of fatal accidents.

In its strongest variant (an intervening version which cannot be overridden), the prediction is that ISA would deliver a 29% reduction in injury accidents. Applying the power model this translates into a 50% reduction in fatal accidents. [Shifting driver behaviour to virtually full compliance with speed limits can cut the number of fatal accidents in half – in a country with good driver compliance patterns. For countries with poorer levels of compliance, the impact would most likely be greater – if drivers accepted the technology. (**See** Speed Management)

ISA TECHNOLOGY

ISA consists of two major elements or sub-systems – informing the driver (all systems) and controlling the vehicle (only applicable to intervening ISA). A visual display and speaker system also need to be provided. Where ISA is installed as original manufacturer’s equipment, the display and speakers are integrated into the dashboard.

INFORMATION

The information part of ISA typically uses a digital road map, enhanced with speed limit information. This can be supplemented with a digital camera on the vehicle that reads speed signs to make up for any gaps in the map. It can also offer real-time information for locations such as work zones.

Digital map providers routinely collect speed limit information and can provide extensive coverage for many countries. Agreements are needed for data exchange between public authorities and commercial map providers to ensure that changes to speed limits are quickly incorporated into maps. One such initiative is the European Transport network ITS Spatial Data Deployment Platform (TN-ITS) which covers a range of road data including speed limits (http://tn-its.eu/).

CONTROL

Many new vehicles, both cars and trucks, currently feature driver-set speed limiters (cruise control) either as standard or as an option. Replacing the driver control with ISA works without driver intervention and is a straightforward technical step.

ISA is a mature technology and the purchase of cars with ISA or with ISA-like features is being promoted. Many fleet management systems incorporate ISA-like capability – with speed infractions by drivers being reported back to the fleet manager. This is known as “recording ISA”. Similar features are also included in many PAYD (Pay as you drive) or UBI (Usage Based Insurance) schemes.

FURTHER INFORMATION AND REFERENCE SOURCES

The European Transport Safety Council (ETSC) has a Frequently Asked Questions (FAQ) section on Intelligent Speed Adaptation which provides a good summary of the current position on ISA implementation - http://archive.etsc.eu/documents/Intelligent_Speed_Assistance_FAQs_2013.pdf

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Nilsson, G., 2004. Traffic Safety dimensions and the Power Model to Describe the Effect of Speed and Safety. *Bulletin 221*. Department of Technology and Society, Lund University, Lund, Sweden

Elvik, R., Vaa, T., 2004. *The Handbook of Road Safety Measures*. Elsevier, Boston, USA

POLICING / ENFORCEMENT

Policing and enforcement have an important part to play in road network operations to improve road safety and to support the efficient use of road space. ITS provides the capability for automated detection and registration of traffic offences such as:

- speeding
- diving through a red light
- close following of vehicles in tunnels
- safe driving hours for trucks
- unlicensed and unregistered vehicles
- vehicles without insurance
- vehicle owners with outstanding fines
- overloading enforcement

Multimedia: Field Test of Mobile Wheel Load Scales

Camera-based ITS solutions can be used for vehicle access control, enforcement of low emission zones ("clear zones") (**See** Environmental and Resource Issues) and traffic offence detection (over height, overweight), as well as moving vehicle offences (speeding). Pictures are automatically taken of vehicles/drivers that violate the rules and a fine is sent to the owner/driver.

Camera-based applications which incorporate Automatic Number Plate Reading (ANPR) include the prevention of through traffic on inappropriate roads (rat running) - such as bus only lanes, residential streets and short-cuts through hospital grounds. By installing ANPR at the control points, details of vehicles entering and leaving can be captured. The availability of a well-maintained and reliable up-to-date vehicle registration database is essential.

Automated enforcement systems for speed limit and traffic signal compliance have proven to be very effective in reducing fatalities and can create increased customer demand for speed alert systems. Many road authorities are now looking at the best ways to promote the deployment of ITS based automated enforcement systems on their roads. Special attention to enforcement on road sections with dynamic speed management (variable speed limits) is required.

Administrative arrangements and legal issues differ from country to country and will dictate enforcement methods and procedures. For example in some countries the vehicle owner is responsible for the offence whoever is driving; whereas elsewhere the police may have to prove who is the driver – so that the enforcement camera image has to show the driver's face. Privacy issues relate to systems that either identify the driver (enforcement systems) or their location. These are often subject to legislation that limits the capture, use and storage of data (**See** Law Enforcement).

The European Union's PEPPER project (2006-2008) is an example of a collaborative study which looked at police enforcement policy and programmes across European roads with the aim of improving its efficiency. (**See** http://www.vtt.fi/sites/pepper/en/police-enforcement-policy-and-programmes-on-european-roads)

PEPPER assessed several aspects of enforcement in relation to speeding, drink-driving and use of seat belts– and focused on:

- detection of infringements

- administrative and legal handling after infringement
- effects of enforcement on road user behaviour and accidents
- enforcement methods and tools
- collection of enforcement data

SPEED ENFORCEMENT

Traditional forms of speed enforcement (such as Gatso wet film cameras) are being superseded by digital photography, eliminating the need to replace the film and requiring lower maintenance and operational costs.

Static speed enforcement measures (spot speeds) can cause rapid acceleration and deceleration as drivers apply their brakes in advance of cameras and then speed up. Average speed enforcement is enabled by Automatic Number Plate Recognition (ANPR) systems which identify vehicles at different positions on the network so that the average speed between two points can be measured. In this way, the speed across the entire length of a road can be enforced, to encourage compliance over longer periods, particularly through areas of temporary traffic management where operatives may be present.

A number of road safety benefits are associated with average speed enforcement. There are generally higher rates of compliance with speed limits with reductions in average and 85th percentile speeds (the speed exceeded by only 15% of drivers) and lower speed variability between vehicles – with consequential reductions in accident rates and in particular, serious and fatal injuries.

Most current enforcement technologies (such as speed warning devices) do not provide feedback to the driver on how they compare with others. Feedback based on collective measures of performance (such as the frequency and level of speeds in excess of the limit) can be significant in changing driver behaviour and improving compliance. The assumption is that most drivers will wish to improve their performance and conform to the actions of others. An ITS solution can use the individual data to provide drivers with an accurate overview of enforcement activity and encourage further compliance.

TECHNOLOGY, DATA & RESOURCES

Spot Speeds

ANPR is a method that uses optical character recognition of digital images to read the licence plates on vehicles. The images are captured on cameras located in a mobile unit or built into law enforcement vehicles or from Closed Circuit Television (CCTV). The ANPR system cross-references the data against existing vehicle registration databases to determine whether the vehicle is untaxed, unlicensed or of any other interest to the police.

Camera errors can be as a result of:

- poor image resolution (if the number plate is too far away);
- blurry images (motion blur, mobile units);
- poor lighting and low contrast;
- objects obscuring (part of) the number plate (vehicle tow bar, high sided vehicles);
- unusual fonts on custom-made number plates;
- circumvention techniques (to obscure number plates – such as reflective lettering).

Average Speeds

Average speed cameras operate using automatic digital technology. Cameras are mounted on columns at the side of the road. By placing the cameras at known points the speed of vehicles can be monitored along a length of road. The cameras are linked by cable or wireless and continuously capture images of vehicles. The number plates are read using ANPR and the average speed of the vehicle between the two cameras is calculated. If this exceeds the speed limit, an offence record is created and the owner contacted with reference to a database of vehicle registrations.

Despite the success of average speed cameras, their use of ANPR highlights a number of practical, social and political issues:

- fears of misidentification - errors within the vehicle licence database can occur due to delays in updating
- limitations with the APNR technology itself – such as failure to capture the number plate, incomplete capture (failure to read all the characters/misreading characters)
- capturing the number plate twice on different cameras on multilane highways as the vehicle switches lane all present problems

"Clock drift" is another phenomenon that may affect reliability, whereby the physical timing mechanisms that are part of the ANPR system as a whole are subject to errors. These can happen for a number of reasons, including temporary power cuts. The subsequent ANPR data may be 'fast' or 'slow'. The set up on the systems can vary and some include an automatic clock readjustment process. The size of the timing errors can be anything from less than 2 minutes to over 8 minutes. This undermines public confidence in using ANPR for speed enforcement and evidence of a speeding offence.

DRUNK- DRIVING ENFORCEMENT

Alcohol consumption, even in relatively small amounts, increases the risk of being involved in an accident for motorists and pedestrians. Alcohol not only impairs critical cognitive processes, such as vision and reaction time, it is also associated with impaired judgement. Road users under the influence of alcohol engage more in other risky behaviours such as crossing traffic in inappropriate places, or not using a vehicle seat-belt where madatory.

Research indicates that a considerable proportion of drivers, motorcyclists and pedestrians have alcohol in their blood in sufficient concentrations to impair their skills – whilst the probability of arrest while driving with an illegal blood alcohol level is low.

Traditional methods of reducing the prevalence of drink driving have included fines, prison sentences, vehicle impoundment and licence revocation – each has a downside. Prison for example is costly.

There is therefore an opportunity for ITS to play a part in the detection of drunken driving. Improvements in alcohol-sensing technology have led to the development of alcohol ignition interlocks. To operate a vehicle equipped with an interlock, the driver must first provide a breath specimen. If the breath alcohol concentration of the specimen is too high, the vehicle will not start.

Convicted drink drivers are sometimes offered the choice of a standard punishment (fine or points on their licence), or have the option for an alcohol ignition interlock to be fitted to their vehicle for a fixed period. Interlocks are typically fitted to vehicles of repeat offenders. The percentage of drivers who have interlocks installed is so low that the device has had little effect on the drink driving population as a whole.

In principle detection of alcohol can be achieved via odour sensors incorporated into the vehicle hardware (such as the gear shift) that can detect the presence of alcohol in perspiration. A warning can then be instigated via the navigation system, providing the driver with information on the nearest safe place to stop (e.g. a service station). The technology is still in development. For example sensors might be placed close to the driver's face to minimise confusion with a passenger's breath. Alternatively facial monitoring could be used although there could be some confusion with fatigue monitoring (eye blinks and closure).

Alcohol detection systems are still being developed and evaluated. As with all enforcement there are privacy issues – except where fleet managers have a no drink-driving policy in place as part of their terms and conditions of employment.

CARRIAGE OF DANGEROUS GOODS ENFORCEMENT

The transport of dangerous goods such as chemicals and dangerous products (known as hazardous materials in the USA or “HAZMAT”) - needs to be regulated in order to prevent accidents to people, infrastructure, other transport and the environment. Different regulations are in place across the world. The United Nations Economic Commission for Europe (UNECE) has issued Recommendations - which, for roads, is elaborated in a UNECE agreement. Although not legally binding, their recommendations are widely accepted internationally. ITS can help support these regulations – for example by monitoring the position of a vehicle, so it can be located efficiently and accurately if an emergency arises. (**See** Enforcement)

The position of a vehicle carrying hazardous goods can be tracked continuously, either actively or passively. In both cases, Global Navigation Satellite System (GNSS) is essential to identify the vehicle’s position.

A **passive tracking system** stores data on the vehicle’s location and other information (such as vehicle condition or container status) which can be examined retrospectively.

An **active tracking system** requires data to be sent by wireless communication to a control room for monitoring in real-time. In addition to location, further dynamic information (such as status of the truck or condition of the dangerous material) can be collected by the on-board unit. Active tracking is valuable in an emergency situation and also has wider benefits. For example:

- it allows control of the shipment along a specified (planned and authorised) route by automatically notifying dispatch and operations personnel when the vehicle deviates from the route. The monitoring centre is also able to advise the driver of a route change for any reason (such as congestion or road accident)
- it can help prevent incidents through monitoring the condition of the vehicle and its dangerous load – an automatic alarm can be raised if abnormal conditions are detected
- it incorporates automatic procedures for recording and logging incidents
- emergency response teams can be informed directly of incidents and provides a facility for two way dialogue between the driver and the dispatcher

OVERLOADING ENFORCEMENT

Overloading a heavy goods vehicle has road safety implications but is also a major factor in the deterioration of road structure of the vehicle.

Safety may be compromised if an overloaded vehicle becomes unstable when driven at the limit of its safe performance. For example, braking distance increases with greater load which may lead drivers to underestimate stopping distances. Risk of tyre failure increases as they heat up under increased load. In addition, if a load is piled high, the raised centre of gravity increases the risk of vehicle rollover. The likelihood that a driver may lose control of the vehicle is greater when the vehicle is overloaded or the load is overweight, unbalanced or shifts its position.

Damage to roads by overloaded vehicles leads to higher maintenance and repair costs and shortens the life of a road. This places an additional burden on the road owner for maintenance and reconstruction. Other road users may carry the associated costs. Overloading also shortens a truck's service life and increases its operating costs and the need for unscheduled maintenance. (**See** Weight Screening)

There a number of ways of monitoring overloading:

- a vehicle inspection station whereby highway transportation personnel weigh vehicles under static state conditions
- load-based toll station charging of vehicles based on monitoring their loadings
- law enforcement patrols whereby personnel weigh suspicious vehicles at random at the roadside using portable weighing equipment (truck scale or weighbridge)
- automatic axle load sensors placed in the road or on bridges

DRIVER DISTRACTION ENFORCEMENT

Drivers rarely “just drive”. There are many different activities a driver engages with, in parallel with controlling the vehicle and maintaining a safe course. Some are considered fairly harmless (such as listening to the radio), whilst others have a more serious impact on driver performance (such as using a mobile phone to text or make a call).

Vehicle manufacturers offer a variety of in-vehicle “infotainment” systems ranging from navigation to email in addition to driver assistance systems such as lane departure warning. All are potential sources of distraction in addition to roadside information and distractions - including large LED advertising displays, Variable Message Signs, roadside advertisements, traffic incidents and accidents on the highway. (**See** Driver Support)

As well as leading to positive changes in driver behaviour and safety, ITS applications for driver safety can also lead to negative outcomes. Attention overload and driver distraction are two examples. The design of an ITS application may present information that is either too frequent or too complex for the driver to process without disrupting the primary task of driving. Other applications which automate or simplify driving may lead to the driver being distracted by non-driving tasks. (**See** Human Factors)

Real time monitoring of driver distraction is not mature enough to be used with confidence. Some vehicle manufacturers have developed “workload managers” which regulate the volume of information presented to the driver at any one time to minimise the risk of driver distraction. For example as a driver enters a roundabout, incoming phone calls are delayed the vehicle manoeuvre is completed. This is work in progress. Sophisticated on-board measurement of driver distraction via camera technology and even the monitoring of brain-wave patterns is being investigated.

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SAFETY OF VULNERABLE ROAD USERS

Mobility is part of daily life. Anyone using the roads is at risk of injury or death in the event of a road accident. Some people are more at risk than others and are commonly referred to as Vulnerable Road Users (VRU). The term has been defined in different ways:

- World Health Organisation in 2013 considered VRUs to be “pedestrians, cyclists, and motorcyclists”
- US DOT’s National Strategy on Highway Safety has a more complex definition: “road users who are most at risk for serious injury or fatality when they are involved in a motor-vehicle-related collision. These include pedestrians of all ages, types and abilities, particularly older pedestrians and people with disabilities. VRU‘s also include bicyclists and motorcyclists. Older drivers may also be considered to fit into this same user group”
- European Union’s ITS Directive refers to “non-motorised road users, such as pedestrians and cyclists as well as motor-cyclists and persons with disabilities or reduced mobility and orientation”

Transport policy makers and road authorities who are responsible for road safety strategies and policies at national and local level need to provide safe road infrastructure that integrates protection for vulnerable road users. ITS technologies can help through:

- design engineering of the road infrastructure to reduce accident risk, manage the conflicting requirements of different road users at critical locations and to reduce the impacts of any incidents
- developing applications that raise awareness of the existence and needs of vulnerable road users, encourage safe road user behaviour by all road users and promote the use of dedicated road safety facilities where provided

Vehicle manufacturers are also exploring vehicle protection systems for Vulnerable Road Users (VRUs). These are often based on forward looking cameras mounted on the vehicle, used in conjunction with other in-vehicle safety applications such as forward looking radars and Collision Warning. (**See** Warning & Control) **Video**: Inside Ford’s Pedestrian Detection System

PEDESTRIANS

Walking is an essential part of daily mobility (if only from a parked vehicle to reach the final destination). As traffic on the roads increases, the potential risk of vehicle-pedestrian collisions increases also. The World Health Organisation’s 2013 statistics show that 22% of traffic fatalities globally are pedestrians.

Vehicle speed is a key factor in pedestrian fatalities. The Australian Federal Office of Road Safety and the UK Department for Transport assessed the relationship between the two. The table below hows a dramatic increase in fatalities at higher impact speeds.

RISK OF PEDESTRIAN FATALITY UPON COLLISION WITH AN APPROACHING VEHICLE

Vehicle speed	Odds of pedestrian death
20 mph	5%
30 mph	37-45%
40 mph	83-85%

The role of ITS applications for enhancing pedestrian safety on the roads include:

- detection of pedestrians at signal-controlled crossings
- speed reduction at the approach to pedestrian-vehicle conflict points (such as school zones) through the use of roadside variable message signs linked to speed sensors or in-vehicle intelligent speed adaptation systems
- improving the visibility of pedestrians through movement-activated roadside lighting and on-vehicle blind spot monitoring systems
- raising awareness of potential conflicts – for example by providing countdown displays at crossings to alert the pedestrian to the green-time available for crossing
- improving vehicle design for pedestrian protection – for example autonomous emergency braking systems which are activated to avoid collision or reduce the force of impact, when a vehicle senses that a collision is imminent

New ITS-based developments include:

- dynamic traffic signal control activated by pedestrians carrying Radio Frequency Identification (RFID) devices that communicate directly with traffic lights
- pedestrian activated warning signs that detect the presence of pedestrians waiting to cross the road
- pedestrian warning lights to highlight for drivers, the presence of pedestrians

The key to putting appropriate measures in place is to identify where interventions are needed - high risk accident zones and locations – and to review the effectiveness of available countermeasures. (**See** Accident Analysis)

FURTHER INFORMATION

WHO (2013) Pedestrian safety: a road safety manual for decision-makers and practitioners.

http://apps.who.int/iris/bitstream/10665/79753/1/9789241505352_eng.pdf

CYCLISTS

Encouragement of cycling as a mode of transport is one way of contributing to sustainable transport objectives. In most countries levels of cycling have declined with increased use of cars, vans and motorised two-wheelers – but an upward trend has been observed recently in highly urbanised areas such as Paris and London linked to deployment of ITS back-office support for city-wide bike hire schemes.

A significant barrier to achieving uptake of cycling are widely held concerns about road safety - due to the amount of traffic on the roads as insufficient provision of cycling-friendly infrastructure.

The role of ITS applications for enhancing cyclist safety include:

- traffic signal prioritisation based on the detection of cyclists - detection can be active (inductive loops) or passive (user activated)
- intelligent cycling infrastructure which reflect patterns of cycle flows within defined areas (such as major destinations – schools, train stations or a university campus)
- bicycle route planning as part of a wider journey planning ITS application supported by turn-by-turn navigation for the cyclist

New developments to benefit cyclists include:

- crowd sourcing of digital maps which take account of road features that are obstructive to cyclists – such as dangerous intersections, cobbled streets, uneven road surfaces, pot holes and steep hills
- bicycle-based devices that enhance the visibility of cyclists to other road users by projecting images ahead of, or to the side of, the bicycle
- vehicle-based cycle detection systems – which are broadly of two types:
  - blind spot monitoring systems
  - systems that communicate with a Radio Frequency Identification (RFID) tag fitted on the bicycle - and other cooperative systems which register the presence of cyclists

The key to putting appropriate measures in place is to identify sites which are of concern for cyclist safety such as problematic junctions and roundabouts – together with assessing user acceptance of specific solutions, whether they are cyclists, drivers or other road users including nearby residents.

FURTHER INFORMATION

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CHILDREN, ELDERLY, DISABLED

Children, elderly and disabled are particularly vulnerable to road accidents. These groups have less resilience to falls or collisions and may have limited mobility. They often rely on mobility aids – walking sticks, wheelchairs and pushchairs. Children in particular have a great propensity to be distracted, and when they gain independence they are often inexperienced in road use and its consequences.

The role of ITS applications that benefit the safety of these vulnerable road users include:

- Speed reduction at potential conflict points such as school zones, hospitals and sheltered housing – for example:
  - Speed Indicator Displays (SIDs) that display a motorist's speed to encourage drivers to slow down (some include a smiling face)
  - in-vehicle intelligent speed adaption
- improving driver awareness of the presence of highly vulnerable pedestrians
- improving vehicle design to assist elderly and disabled drivers including in-vehicle information and control systems such as:
  - collision warning system, blind spot and obstacle detection systems, and e-call
  - routing advice to avoid specific types of road (such as motorways)
- "intelligent" facilities for pedestrians – for example extending pedestrian crossing time for signalised

crossings at appropriate locations. These can be enhanced by features that help people who have a sight or hearing impairment (using tactile and audible prompts)

The key to putting appropriate measures in place is to identify installation locations where pedestrians are at risk – such as crossing points or junctions adjacent to schools, nursing homes, or a high concentration of disabled pedestrians.

ROAD WORKERS

Roadworks occur all the time on the network. Highway authorities and road operators carry out maintenance and improvement works such as road widening, resurfacing, bridge and gantry maintenance, white line painting, litter collection and gully emptying. The providers of utilities such as gas, electricity, water, sewage and telecommunications - also carry out maintenance and repairs to their infrastructure located alongside or below the road.

Road workers are commonly exposed to serious risk of accidents and fatalities. Vehicle speed is often a key factor in road worker fatalities. The role of ITS application in reducing these risks include:

- information and advance warnings to drivers through dynamic signs about the presence of road workers - including the temporary deployment of portable dynamic signs
- speed management using variable speed limits and camera enforcement. Automatic Number Plate Recognition (ANPR) can be used to support enforcement or to display an offending vehicle's registration number on a dynamic message sign to influence driving behaviour

The key is to make drivers aware of the presence and vulnerability of road workers. (**See** Work Zones)

FURTHER INFORMATION

Safety at street works and road works: a code of practice 2013 (UK)

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/243997/safety-at-streetworks-tagged.pdf

US Department of Transportation: work zone mobility and safety program

http://www.ops.fhwa.dot.gov/wz/its/index.htm

WORKING ANIMALS

Working animals include guide dogs that help the visually impaired people and horses carrying riders or pulling carts that share the roadway. All are at risk of accidents, many of which are preventable.

There is very little reported experience of technology solutions for working animals. A potential application – for guide dogs and visually impaired people - would be cooperative systems which combine geo-location with communications - for example:

- between the guide dog and the road infrastructure and/or vehicles
- and by providing voice guidance and safety messages to the person at dangerous locations

This could be achieved through a combination of Global Positioning Satellites and Radio Frequency Identification. A similar concept might be appropriate for horse riders and horse drawn carts – enabling communication between the equipment worn on the animal and the road infrastructure.

INFORMATION AND WARNING

Road users interact with their surrounding environment. Information and safety warnings are provided to drivers during a journey in various ways:

- roadside variable message signs (**See** Use of VMS)
- in-vehicle information systems (**See** Advisory Systems)
- smart phones and other portable devices as well as in-vehicle radio(**See** En-Route information)

Multimedia: Volvo Wild Animal Warning

The concept of the "Self-Explaining Road" builds on the interaction of the road user with the environment – by promoting the idea that roads should be understandable to the road user. This is achieved through traffic engineering design supported by clear, consistent and readable roads signs and information to road users to guide them intuitively. Safe design is aimed at encouraging safe road user behaviour.

Modern signing systems have been used since the beginning of the 20th century. Road signs serve a common purpose: to communicate information or provide warnings to road users. Until the 1970s most signs were static. Today dynamic signs are widely used – they exploit information and communication technology and are a key component of ITS as part of the process of bringing together information collection, its integration and dissemination.

Early models of dynamic signs used rotating panels or lamp matrix signs for displaying directional/diversional information or advisory speed limits. More recent models allow greater flexibility in the range of information that can be displayed to road users – such as traffic conditions, incident warnings and road safety campaign messages.

One of the main purposes of dynamic signs is for traffic management – to manage incidents and mitigate their impact – by providing warnings of incidents and diversion advice and regulating traffic flow through variable speed limits. (**See** Use of VMS)

There are three major groups of stakeholders in the provision of safety information and warnings across the road network:

- road owners, operators and traffic police who are responsible for infrastructure provision and everyday operation of highways and road networks
- equipment manufacturers and suppliers, who must respond to specifications and design guidelines, the practicalities of operating a road network and the needs of road users including their likely perception and behaviour
- road users themselves, who need to be able to easily interpret the information and warnings – and therefore need to be consulted on the design of signs and messages.

DESIGN CONSIDERATIONS

There are several aspects to the design of information signs and warning systems for the road operators to take into account before putting in place solutions to specific problems:

- information overload
- driver awareness, attention demands and level of compliance

- design of text based dynamic signs
- standardisation

Information overload refers to the situation where there are too many signs along a stretch of road or at a single location. Dynamic signs may provide advantages over static sign if the display can be turned off when not needed (for example weather related warnings for ice or flooding). They can also be made to activate on detection of an approaching vehicle – usually in response to excess speed to get the attention of the individual driver.

Driver awareness of messages and their compliance can vary considerably and are influenced by the content of the message, its context and the road user's previous experiences. Poor management of information signs can lead to lack of confidence – for example failure to remove a warning message when a traffic incident has cleared.

Driver attention is affected by the format of the display. Text messages tend to require greater levels of attention than symbols or pictograms. Drivers generally have a preference for pictograms although they are not necessarily always understood. Signs which change in real-time also impose higher attention demands compared to fixed signs. Readability and comprehensibility are affected also by the content of the message and how it is formatted. Splitting a long message into two short lines instead of one can shorten the response time – as can using a two-coloured display.

Design of text based dynamic signs is constrained by the limited space available which constrains the length of the message. Drivers tend to read messages in a series of short glances. The time frame available between first seeing the message and passing by may be quite short, even at low speeds. Prevailing driving conditions will influence how much attention the driver is able to give to reading and understanding the message.

Standardisation of static signs has been developed over a long period beginning with the Geneva Convention on the Unification of Road Signals, 1931. Dynamic signs, by contrast, are not yet standardised to the same extent – at either the national or international level.

QUEUE WARNINGS

Queue warnings are an effective contribution to managing traffic on high speed roads. They serve three objectives:

- to avoid rear-end collisions when traffic is required to slow down and queues begin to form
- to protect against secondary collisions when the traffic ahead is stationery following a collision
- to divert traffic away from an incident that blocks the highway to prevent queues from becoming longer by re-routing traffic across the local and regional road network

Effective queue warnings for network management require:

- real-time monitoring of traffic flow and vehicle speeds
- advance warning of the queue appropriate to the traffic situation which relates to traffic flow and highway capacity (for example, "Queue Ahead" displayed on VMS two miles ahead);
- advisory messages over a wide area, of disruption, to enable drivers to re-route their journeys if necessary (**See** En-route Information)
- prompt cancellation of warning messages – the display of out of date message affects driver confidence and trust in warning systems

Queue warning systems therefore rely on rapid incident detection and warning technologies which:

- automatically detect abnormal flows and speeds – for example by means of camera-based image processing systems, induction loops or above ground sensors
- enable visual confirmation of automated detection systems using traffic surveillance cameras
- activate warning messages on dynamic signs (automatically or manually by traffic control room operators)
- activate variable speed limits where appropriate (automatically or manually by traffic control room operators)
- activate diversions where appropriate (in some cases this is done automatically or more often, manually by traffic control room operators with reference to a traffic management plan) (**See** Traffic Management Plans)

In addition to road-based solutions, automotive manufacturers are developing collision warning systems that make use of on-board radar and sensors to detect obstacles (such as stationary vehicles ahead) to warn the driver or activate autonomous braking.

Cooperative vehicle systems communications - car to car (C2C) or car to infrastructure (C2I) - are able to warn drivers well ahead of an incident or queues forming (**See** Warning and Control Systems).

FURTHER INFORMATION

Queue warning systems (**See** http://mobility.tamu.edu/mip/strategies-pdfs/active-traffic/executive-summary/queue-warning-1-pg.pdf)

Portable End-of-Queue Warning Systems (**See** http://tti.tamu.edu/enhanced-project/facilitating-deployment-decisions-of-highly-portable-end-of-queue-warning-systems/)

BROKEN-DOWN VEHICLE WARNING

The reason for deploying broken-down vehicle warning systems is to prevent rear-end collision and secondary collisions. They follow similar principles and use similar technologies as queue warning systems:

- incident detection to provide warnings to drivers using dynamic message signs and to activate variable speed limits
- in-vehicle forward collision warning systems
- Dynamic Lane Merge Systems (DLMS) which make use of dynamic signs to facilitate vehicle merging at the approach to lane closures

eCall is a European collision notification system aimed at summoning rapid assistance to motorists involved in a collision anywhere in the European Union countries. It uses GPS and digital cell-phone communications (such as GSM) to automatically initiate a 112 emergency call to the nearest emergency centre. It transmits the exact geographic location of the accident scene and other data. Such services are valuable for saving lives – in particular for single vehicle accidents in rural/remote areas. (**See** http://www.heero-pilot.eu/view/en/ecall.html and DRIVE C2X project http://www.drive-c2x.eu/use-03)

FURTHER INFORMATION

Breakdown Safety Strategy: A way forward. September 2012. Transport for NSW, Australia. (**See** http://www.mynrma.com.au/media/rms_breakdown_safety_strategy.pdf)

WILDLIFE

Road-side animal detection systems are deployed in some countries to prevent crashes involving large animals. There are potential dangers from free roaming cattle, wild horses, elephants, moose, kangaroos, bears and reindeer. The systems alert drivers to potential collisions with animals and rely on radar, lasers and other imaging techniques to detect the presence of animals on the roadway.

There are broadly two approaches to detection:

- area sensors that register the presence of large animals within a certain range using infrared light or microwave radio signals – and which can be enhanced with algorithms to distinguish between animals and other moving objects in order to avoid a false detection
- break-the-beam sensors which respond when an animal crosses the beam between a transmitter and receiver. The beam can be infrared, laser or microwave radio signals

False alarms are the main problem, triggered by wind, rain or overgrown vegetation. Sensors can be adjusted, but it is very difficult eliminate false alarms completely whilst still ensuring that the target animals are detected. The frequency of false alarms should be monitored and adjustments made to the detection sensitivity of sensors – for example in advance of adverse weather conditions or in different seasons.

FURTHER INFORMATION

Sharafsaleh, M. and Huijser, M. (2012) Evaluation of an animal warning system effectiveness. California PATH, Richmond, CA, USA. Report number UCB-ITS-PRR-2012-12. (**See** http://www.dot.ca.gov/newtech/researchreports/reports/2012/2012-06_task_2090-tsm.pdf)

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Megan Bayly, Brian Fildes, Michael Regan, Kristie Young (2007) Review of Crash Effectiveness of Intelligent Transport Systems (**See** http://www.trace-project.org/publication/archives/trace-wp4-wp6-d4-1-1-d6-2.pdf)

NEW AND EMERGING APPLICATIONS

“Cooperative Systems” use communication between vehicles and between vehicles and the infrastructure (roadside equipment and traffic control centres) to provide drivers and other road users with real-time information. Vehicle-to-vehicle (V2V) communication applications include Cooperative Cruise Control and vehicle platooning (where vehicles are coupled into platoons with an “electronic tow-bar”). (**See** Coordinated Vehicle Highway Systems)

Vehicle-to-Infrastructure (V2I) applications have an important role to play in road safety by gathering, processing and exchanging information on traffic and road conditions from different sources on the network (locally and regionally) to develop information warnings and vehicle control instructions. For example vehicles can be alerted to slippery road conditions where the trigger might be icy road sensors at an exposed location or a skid registered by a vehicle.

Currently cooperative systems tend to be expensive. That is because the technology requires high bandwidth and very reliable and rapid (low latency) communications - which are costly. Specialised wireless communication, known as DSRC (Dedicated Short Range Communications) is potentially the high-end emerging standard. It uses a microwave or infrared communications with added security features. It is likely that DSRC cellular communications for V2I/I2V systems and services, will only be economically feasible in so-called "hot spots" of the road network such as tunnels, accident black spot intersections, signal-controlled intersections.

Besides the cost, a major obstacle to the use of cooperative systems, particularly V2V systems, is that there is little benefit to early adopters. Unless there are other equipped vehicles with which to communicate, the technology cannot interact. This is in contrast to autonomous systems such as Forward Collision Warning or Lane Departure Warning, where the equipment can have immediate benefit for the driver.

Cooperative Systems in the USA

The United States National Highway Traffic Safety Administration (NHTSA) has announced that it is considering requiring new vehicles to have connected vehicle (V2V) capability using DSRC. The expectation is that mass production will lower the cost of the V2V communication units and that government will develop a programme for installing DSRC roadside infrastructure.

V2V technology has the potential to be fused with existing vehicle safety features to further improve the effectiveness of many crash avoidance safety systems currently being developed and implemented in the vehicle fleet - and will serve as a building block for a driverless vehicle. Vehicles equipped with V2V technology could also enable the development of a wide range of mobility and environmental benefits based on vehicle-to-infrastructure applications and other V2V applications that can enhance traffic flow in many ways. V2V technology does not involve collecting or exchanging personal information or tracking drivers or their vehicles.

There are also moves to develop cooperative systems that use readily available technologies such as GPS combined with 3G and 4G mobile communications. One example is TomTom’s “Jam Ahead Warning” system, which alerts drivers to slow-moving traffic ahead of their current position. The system uses the real-time speed profile of users of TomTom navigation devices that are fitted with mobile data communications. The system identifies in real-time when traffic speeds are unusually slow and broadcasts an alert to other vehicles fitted with TomTom units in the locality. The advantage of autonomous systems such as this is that they can be implemented immediately without the requirement for installing expensive dedicated communications technology and infrastructure.

Other cooperative systems being trialled use roadside equipment to communicate with drivers. An example is intersection collision warning. Many proposed applications of cooperative systems are comparable to current use of Variable Message Signs. There is scope also for the development of safety applications based on Human-to-Vehicle (H2V) communications.

INTERSECTION COLLISION WARNING

Safety at unsignalised intersections can be a major concern. Intersection collisions are one of the most common types of crash and tend to be severe particularly on rural roads. That is because collision speeds are often high and occupants are less well protected against side impacts compared to frontal collisions. The high speed of main-road traffic can exacerbate the situation.

Many rural intersections use static stop signs or give-way (yield) signs to control side-road traffic. The driver has to judge when there is a safe gap to join the main road traffic. Only the nearside gap needs to be assessed when the driver is not crossing the near-side traffic flow. Where the driver needs to cross the traffic flow, the task becomes more difficult. Multilane roads increase the difficulty.

Intersection collision warning systems use multiple sensors installed at the roadside to track vehicles as they approach, linked to sophisticated algorithms that determine whether gaps in the traffic are safe or unsafe (above or below a critical threshold). Signs to help the driver decide whether to make the manoeuvre are located where they can be seen by drivers at the stop or give-way sign – such as in the photograph in the box below.

Cooperative Intersection Collision Avoidance System (CICAS)

The University of Minnesota has developed the Cooperative Intersection Collision Avoidance System (CICAS) to improve safety of vehicles turning into or crossing rural divided highways. The initial development was in a driving simulator, followed by real-world implementation.

CICAS informs drivers at stop-signs when gaps between vehicles approaching on the main road are not large enough - see http://www.its.umn.edu/Research/FeaturedStudies/intersections/cicas.html.

The warning system is deployed at three intersections in Minnesota and one in Wisconsin - at high-risk locations. The Minnesota Department of Transportation is rolling out a refined version of the system to intersections across the state (2012-2015). It is known as the “Rural Intersection Conflict Warning System” (RICWS).

The layout of a warning sign at a trial location (source: University of Minnesota, ITS Institute)

Detailed information on the development of CICAS can be found at http://www.its.umn.edu/Research/ProjectDetail.html?id=2006050.

VULNERABLE ROAD USERS TO VEHICLE COMMUNICATION

Currently most vehicle protection systems for Vulnerable Road Users (VRUs) are based on forward looking cameras mounted on the vehicle, used in conjunction with other in-vehicle safety applications such as Forward Collision Warning. As mobile communications mature at a rapid rate there is potential to develop safety applications based on Human-to-Vehicle communications. (**See** Vulnerable Road Users(ITS & Road Safety) and Vulnerable Road Users(Human factors)

To be reliable, the technology needs to be able to detect, classify and track relevant objects and disregard false alerts. The technology also needs to be readily accessible - at an acceptable cost for the user, wearable, easy to use and have low power consumption. In addition, the technology needs to cope with complex situations where people are obscured by other objects such as parked vehicles. In-vehicle equipment must have the ability to detect pedestrians or cyclists at intersections where a high proportion of incidents occur.

If Human-to-Vehicle communication systems are to be successful, the take-up needs to be relatively high. The technology is near-market so there is need for decisions on the appropriate user communication interface. For example:

- does the driver receive a warning or should the system provide autonomous braking?
- how should warnings be presented - in what mode, with what frequency, and how should they be prioritised, given the multitude of other warnings present in vehicles?
- how should the vulnerable road users be alerted (if at all) - and what type of advice should be given?
- in the case of young children, what types of messages are easily understood and acted upon?

Human-to-Vehicle Communication Developments

Approaches which combine video detection on the vehicle with real-time positioning systems for the vulnerable road user are being developed to provide warnings of each other's presence. For example cooperative sensor technology via RFID tags can be integrated into school bags, clothing, helmets or mobile phones. In-vehicle location devices can transmit a continuous query to the RIFID tags to obtain information on the location, trajectory and speed of the road user. The objective is to calculate risk and warn of a possible collision. An example is Japan's Pedestrian Information and Communication System to enable the elderly and the disabled to move around safely.

See: http://www.utms.or.jp/english/system/pics.html

Smart phones offer another promising platform and a communication interface for new applications.

Privacy issues – which may be sensitive for some user groups, such as children and vulnerable adults - will need to be addressed. Whilst a RFID tag may not identify a specific person, public concerns may be high and lead to low uptake of applications.

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