Appendix

Short descriptions of ITS safety applications and their potential safety benefits

Picture: IVSS

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Appendix: Short descriptions of safety applications and their potential safety benefits

A classification of safety applications according to risk situation (exposure, risk, consequences) is used here. This systems approach was used buy a working group within the European Traffic Safety Council (ETSC)[1]. Most ITS-applications seem to influence the collision risk and the active safety.

Traffic exposure	**Crash risk (active safety)**	**Crash consequences (passive safety)**
Demand management	Speed Adaptation	Crash course correction
Travel planning	Collision Avoidance	Occupant protection
Route guidance	Local risk information	Pedestrian / cyclist protection
Freight and fleet management	Vision enhancement	Emergency notification
Selection of road users	Lane keeping	
	Driver and vehicle monitoring	
	Policing and tutoring	
	Incident management	
	Flow control	
	Urban traffic control	
	Vulnerable road users	

In the following sections we will try to define the various applications, give an idea of how the safety benefits will arise, discuss conditions that should be met to reach the full potential and estimate if the application might give a substantial contribution to safety in the future. Substantial is here defined as more than 0,5% influence on fatalities and severe injuries.

In section four is a preliminary estimate of the safety benefit potentials made. We present three different estimates.

- the verified potential using reasonable reliable studies and field tests
- predicted potential, which is identical as the total potential in the main report and
- full potential, which is an optimistic estimate, which can be used as a stimulus for further research and development in eSafety (EU) and IVSS (Sweden) programmes.

[1] European Traffic Safety Council. Intelligent Transport Systems and Road Safety. 1999.

1 Reduction of traffic exposure

Traffic reduction is primarily an environmental objective. However, exposure is one of the main variables of road safety. Research and experience demonstrate that if total vehicle mileage is reduced, then the number of crashes on average will also be reduced. Basically, any measure reducing the need for transport will contribute to this objective.

1.1 Demand management

DESCRIPTION

Demand management aims at reducing the amount of transport by physical or financial restrictions. In terms of ITS, the most common measures are access control and electronic road pricing schemes. (ETSC)

OVERVIEW

An efficient way of reducing traffic in a town centre or similar is to apply an access control scheme where only authorised vehicles are allowed to enter the area. Electronic road pricing schemes cover a variety of systems: Tolls, Cordons (Toll rings) and also Distance and time based systems.

SAFETY BENEFITS

Safety benefits will arise if the traffic volume is reduced or users change to more safe means of travel. The effect on traffic and consequently on safety depends largely on the topography of the surrounding road network. If alternative routes are free of charge, drivers may be tempted to divert to them. In Austria, the estimated diversion of traffic from the motorway was between 5 and 20 per cent, depending on the capacity of the secondary road network. This illustrates that from a safety point of view, motorway tolling is not necessarily an advantage as drivers may choose less safe routes.

In Stuttgart, a large field trial has been carried out to investigate the impact of variable road pricing charges. The trial showed that 12 per cent of the car trips were moved to a cheaper period, 15 per cent changed to a cheaper route and only 5 per cent changed to public transport. Car sharing increased to cover 7 per cent of all trips. The change in destinations was negligible (Mock-Hecker & Schnittger, 1997).

POTENTIAL

The condition to realize the full potential of road pricing is that the charges are high, which up to now has resulted in political problems. Congestion pricing is usually proposed for small areas. A possible system for Stockholm, which should be tested in 2005 will affect 10% of the region but only 1-2% of the total traffic volume in Sweden. A possible reduction of this traffic with 5-10% will consequently give only marginal safety effects. It is not probable that demand management will give substantial nationwide safety benefits (over 1%) as defined above. Demand management is therefore mainly a function that influences congestion and the environment.

1.2 Travel planning with ITS

DESCRIPTION

Travel planning with ITS include support for choice of transport modes and routes, time of trip etc. mainly before the trip.

OVERVIEW

In the field of ITS, travel planners have been developed on an off-line basis. The typical solution is based on the Internet giving the answer of how to get from A to B taking various requirements into account. This may be time of arrival, time of departure, travel time, travel cost etc. (an example in Danish can be found on: www.rejseplan.dk).

In future, travel planners based on Personal Digital Assistants (PDA) will be available as a mass product. The PDA's are already on the market for personal planning etc. Since they can be carried everywhere, they will permit very dynamic planning procedures. Mounting units for car use are available. Likewise, specific car computers including travel planners and route guidance systems are on the market.

Travel planning can also support **car sharing** and **park-and-ride**. Certain systems for car-sharing have evolved on a local basis based on the Internet or the Intranet of certain companies. Communication technology may also replace physical transport to a certain extent. Although it is outside the traditional scope of ITS, distance working (tele-working, tele-commuting etc.) should be mentioned. Even if **tele-commuting** does not change the total exposure, it may affect the departure time and consequently contribute to less rush-our traffic which in turn may reduce the accident risk.

SAFETY BENEFITS

A modal shift from car to public transport will generally increase traffic safety as the risk level for public transport is lower. However, when comparing the two alternatives, the total trip including walking etc. should be considered.

Travel behaviour can be affected by ITS applications that mainly provide the traveller with a better basis for decisions in terms of traffic and travel information. In particular, better information about public transport is an important prerequisite to get drivers to change from car to bus or train (CEC, 1993).

POTENTIAL

The full potential may be realized if travel planning increases the use of car-sharing, park-and-ride and public transport. In this case substantial effects can be expected. It is however more realistic to influence trip departure times, which will have less influence on overall road safety.

1.3 Route guidance

DESCRIPTION

Static route guidance supplies the driver with stored information of an individual route on the basis of the normal driving conditions. Congestion / traffic information includes realtime-information of the current situation. Dynamic route guidance includes optimum routes in the network calculated on the basis of the criteria (time, distance, cost) suggested by the driver.

OVERVIEW

Route guidance systems range from simple navigation systems based on digital maps to dynamic route guidance systems based on actual traffic information. Several autonomous systems are available on the market and the driver interface ranges from a map with the location of the car and the destination to a display with an arrow showing the driving or turning direction.

Static route guidance
On the basis of the input of an origin-destination pair, a route choice algorithm calculates the optimum route using the criterion of the shortest travel time. Restrictions may be included in the system in such a way that through traffic is avoided on residential streets and other sensitive roads.

Congestion / traffic information

Information to the driver about the traffic and congestion situation for choosing the most effective route. Access to the information can be mobile telephone, Internet or RDS-TMC.

Important is the actuality of the information about the traffic situation to maintain the credibility of the function (eSafety). Weather information can be included as well as restrictions for through traffic.

Dynamic route guidance
The same as congestion/traffic information but integrated in the vehicle system and including optimum route calculation.

SAFETY BENEFITS

Static route guidance
As one of the main driving tasks in an unfamiliar area is to find the way to the destination, a route guidance system can reduce the stress on the driver and release mental capacity to better observe and react in traffic. In theory, the system will also reduce exposure as the amount of unnecessary driving is reduced. The route guidance facility may on the other hand create new trips because drivers feel comfortable going to unknown destinations (CEC, 1998).

A problem is that route guidance systems do not always consider the relative risk between different routes. An obvious improvement would be to add to the traditional optimisation criteria (the shortest or the fastest route) a new option: the safest route. In theory, this would require a large amount of accident statistics to be added to the digital maps on which the route calculations are based. In practice, however, estimates of the accident risks of certain road types would be a reasonably good approximation (ETSC).

Results concerning route guidance systems are varied and contradictory. Some results indicate that the systems decrease exposure by directing drivers to their destination along the shortest routes and without the need to look for the destination by driving around. Other results indicate that owners of these systems start to make new trips to places that they are not so familiar with, thus increasing exposure. It is also clear that in-car route guidance systems distract the drivers from their normal driving task, but, on the other hand, to a lesser extent than a conventional map (CEC, 1998; Ståhl, Berntman & Petzell, 1997 and Winkler & Nowicki, 1997).

Dynamic route guidance
A route guidance system guides the driver along the fastest (or shortest) route to his destination. The Human Machine Interface is crucial for the safety value of these systems. Systems based on map displays should not be used when driving. It is also important that the route guidance system is of a certain quality: this means that the database is detailed enough to cover the whole trip to a certain address, shop, hotel or parking ground. In urban areas it is crucial that the system includes all one-way streets and turning bans to avoid confusing and dangerous driving situations. Maps must be up-to-date and the location system of the vehicle must be accurate in order to avoid confusing or dangerous driving situations.

A special type of route guidance is **parking guidance** systems based on variable message signs (VMS) along the streets. The idea of giving information about available parking space is good, but this is an example of an intermediate technology (VMS). However, it addresses everyone in the same way regardless of the driver's need. An in-car solution based on a request from the driver would be safer, more efficient and more environmentally friendly.

Quantitative analyses show very small accident reductions due to dynamic route guidance systems but a risk for more accidents if route diversions from motorways are frequent (Federal Highway Administration, 1997a; Elvik, Borger Mysen & Vaa, 1997 and Perrett & Stevens, 1996).

POTENTIAL

The full potential of route guidance systems will arise if user criteria are included, if local risk information is included, if preference for safe roads is built into the system and if the HMI issues are treated seriously. These factors must be built in if safety benefits should be substantial. A common characteristic for route guidance and travel planning systems is that they optimise an individual's trip or route. This does not necessarily correspond with the total optimum from the societal point of view. As an example, short cuts through residential areas are undesirable for many reasons. Some sort of public regulation may be required, for example, so that the navigation databases include only major roads.

1.4 Freight and fleet management

DESCRIPTION

Freight and fleet management include Vehicle Positioning, Dynamic Fleet Management and Hazardous Goods Monitoring.

OVERVIEW

Commercial vehicles account for a large proportion of urban traffic while heavy goods vehicles are more common on European motorways. Accidents involving heavy goods vehicles generally have severe consequences in terms of damages and injuries. There are potential benefits in better management of freight and fleet operations.

SAFETY BENEFITS

The use of Mobile Data Communications, Global Positioning Systems (GPS) and Trip Recording could lead to a substantial reduction in the total distance travelled by commercial vehicles. In terms of hazardous goods monitoring and control, a significant reduction of alert time from the usual hours to a few minutes has been noted (CEC, 1998).

A British desk study indicates that the implementation of freight and fleet management systems is expected to reduce accidents mainly due to less distance travelled (Perrett & Stevens, 1996). The savings in mileage are estimated to be 3 per cent.

POTENTIAL

A special case of freight and fleet management is what is called “**city logistics**“, dealing with the optimisation of goods delivery operations in urban areas. The aim is to reduce freight and delivery traffic and to perform the necessary transport operations with more appropriate vehicle types. The effect on the total exposure has not yet been described, and there are contradictory measures in use. One of the attempts is to use smaller and more appropriate vehicles for urban traffic but this will all other things being equal increase the total mileage.

The CHAUFFEUR Tow-Bar system is an **electronic coupling** of heavy goods vehicles. The leading truck is driven conventionally by a driver while the second one follows automatically (Schultze, 1997). The system can increase the efficiency of heavy goods transport considerably. At the same time it will reduce the exposure as the platoon of trucks may be considered as one (although very long) vehicle. It is difficult to assess the overall safety effect as the new combined vehicle has quite different physical characteristics in terms of length, weight and manoeuvrability. In particular, the system safety of the electronic coupling is of crucial importance. Furthermore, the interaction between CHAUFFEUR equipped platoons and conventional traffic requires extensive studies.

The full safety potential will arise if fleet management is used to reduce total mileage and control hazardous goods. Electronic coupling is an interesting science fiction option, but will evidently take many years to develop to a fail-safe system.

1.5 Selection of road users

DESCRIPTION

Selection of road users include Electronic Driving Licence and Alcohol Interlock

OVERVIEW

Recent development has made it technically possible to identify at least two types of unqualified drivers before they switch on the engine: drivers without a valid driving licence and intoxicated drivers.

Electronic Driving Licence
The driving licence is a smart card containing personal information about the driver, including which vehicle types or even individual vehicles he or she is authorised to drive. The smart card serves as an ignition key, and the vehicle will only start if there is correspondence between the card and the vehicle unit (Goldberg, 1995). Systems for voice recognition has also been tested, which would assure that no unauthorized person should have access to the vehicle.

Alcohol Interlock
Systems to prevent drunk drivers from operating a vehicle. The system analyses indirectly blood alcohol content and determines if a driver is within a legal limit to get behind the wheel. In order to start the vehicle, a breath sample must be given. If a certain level of alcohol is read, the vehicle will not start. The setting can be adjusted as necessary to any required level.

SAFETY BENEFITS

Electronic Driving Licence
A field trial with 15 vehicles has been carried out with support from the Swedish Road Administration. Myhrberg (1997) concludes that the concept works in practice and that it could have great effect on traffic safety by preventing unauthorised driving and car theft. The users have no problems getting used to the Driving Licence and in general their attitude to the new system is positive. There are, however, many practical issues to be solved before a large-scale introduction can take place.

Alcohol Interlock
Alcohol Interlock is especially used in two situations: Quality assurance of professional transports and as an alternative to cancellation of driving license for drink-drivers. Safety benefits arise thank to less traffic made at inproper driving conditions. Studies of effects on professional drivers have been made in Växjö, Borlänge och Göteborg in Sweden. In Borlänge, 63 % of all companies that have been taken part in the trial, believe that the safety

increases[2]. In Canada and USA, it has been registrered that the number of repeated sentences for driving under the influence of drugs or alcohol have decreased with 40–95 %[3].

POTENTIAL

The potential is already proven to be substantial and an even greater potential will arise if both systems are combined. In this case, it may be a requirement on the intelligent driving license that a particular driver must perform the test before driving. This could be used for repeat excess alcohol offenders. Other types of ability tests could also be included. Furthermore, certain requirements or limitations to the driver could be included, e.g. maximum speed level for new drivers, restricted driving hours of the day or restricted routes. The concept is very promising and deserves major attention on a European basis.

[2] Markör (2000). *Entreprenörernas syn på alkolås, en utvärdering av alkolåsprojektet i Jönköping och Växjö. Delrapport 2.*
[3] ICDTS Working group on Alcohol Ignition Interlocks (2001*). Alcohol Ignition Interlock Devices I: Position Paper.*

2 Reduction of crash risk (active safety)

2.1 Speed adaptation

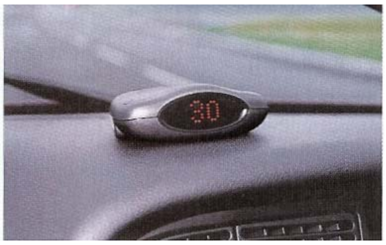

Photo: Traffic Technology International

DESCRIPTION

Speed adaptation includes both infrastructure systems as variable speed limits and vehicle-based systems as Intelligent speed adaptation (ISA) and Curve Speed Information.

OVERVIEW

Variable speed limits
Speed limits are varied and adapted according to weather, road surface, light and other external conditions.

Intelligent speed adaptation
Intelligent speed adaptation systems limit the vehicle speed and can be divided into:

- informative / warning, where audible / visual / haptic signals are used to make the driver aware of excessive speed
- intervening, where the vehicle automatically adjusts the speed or obstructs further increase in speed.

Also the judgement of correct speed can be made in different ways : *Dynamic* systems use sensors to monitor weather, road surface, traffic flow, distance to the vehicle in front to judge correct speed. *Static* systems use only information about current speed limits.

Curve Speed & Speed Limit Info
Recommendation of an appropriate speed calculated with inputs from different sensors and sources such as curve-geometry and static speed limits or information from outside.

Speed camera alert
A recent application is speed camera alert. It is alerting drivers of the presence of fixed speed cameras, roadworks mobile cameras and variable speed gantry systems. As the risk of speeding fines is more evident to the drivers than the experienced risk, a market exist for a more limited system. Also such a system has small safety benefits. Peugeot e.g. sells such systems for £325 on the British market[4].

[4] Traffic Technology International. Aug/Sept 2003 p.10.

Safety benefits

Variable speed limits
Variable speed limits that can be varied according to weather, road surface and light condition can give substantial safety benefits as the drivers typically underestimate the danger and overestimates the suitable speed in these conditions. There are probably also indirect effects as the acceptance for and the compliance to the speed limits may improve if the limits are experienced as more reasonable.

A variable speed limit system integrated with a fog warning system reduced the number of injury accidents on a German motorway by around 20 per cent (Balz & Zhu, 1994), and a variable speed limit system integrated with a slippery road warning system on a Finnish motorway by around 10 per cent (Rämä, 1997). Both studies reported significant reductions in mean speeds (3 to 9 km/h) in adverse weather conditions, and the latter also a significant decrease in speed variation. Variable speed limits have also been applied by schools, resulting in a 20 per cent accident reduction (Elvik et al., 1997).

Intelligent speed adaptation (ISA)
Safety benefits will arise from ISA as excessive speeds will reduce. SNRA[5] has within the framework of the Swedish ISA trial, studied both informative systems and intervening systems as "active accelerator" in urban areas. These systems are expected to have a great positive influence on the individual drivers that use ISA, but also to influence other vehicles by slowing down the tempo in urban areas. The share that drives too fast was reduced from ca 30% to ca 20%. The share that drives more than 10 kph too fast was reduced from ca 15% to 5% with informative systems and practically to 0% for active accelerator[6].

Curve Speed & Speed Limit Info
Safety benefits may arise if the recommended speed in curves is set lower than the speed limit. As long as ISA not is standard equipment, curve speed information may be more accepted and complied with, as it is more experienced as a risk situation by the drivers than normal driving conditions.

Potential

Intelligent Speed Adaptation (ISA) is one of the most promising safety systems, and has been estimated to reduce accidents by around 35 per cent[7]. The full potential will arise with a compulsory and intervening system used on all roads and taking advantage of the possibility to vary speed limits more than today dynamically and geographically in response to the driving conditions. Várhelyi (1997) has estimated that automatic speed limiting on rural roads would reduce the total number of injury accidents in Sweden by about 10 per cent. ISA in conditions of low friction would decrease the total number of injury accidents by around 12 per cent and ISA in darkness by 12 per cent.

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[5] Swedish National Road Administration.
[6] Vägverket (2003). *ITS Effektsamband, uppdatering av Effektsamband 2000 med avseende på ITS.*
[7] Carsten & Fowkes, 1998; Gustafsson, 1997 and Lind, 1997

2.2 Collision avoidance

DESCRIPTION

Collision avoidance covers a number of systems ranging from Adaptive Cruise Control (ACC), Adaptive Brake Lights and Obstacle Warning to actual Collision Avoidance Systems as Emergency braking.

OVERVIEW

Adaptive Cruise Control
ACC maintains a constant safe distance to the vehicle in front, automatically reduces speed if the vehicle in front slows down, and automatically increases speed if the vehicle in front picks up speed. In the event that the vehicle in front makes a lane change or speeds away, the own vehicle accelerates till it reaches a preset cruising speed of the conventional cruise control[8].

A variant is *ACC Stop & Go*. It includes distance control even at low speeds (down to zero). After turning on the system, it keeps the set speed or if not possible the set distance.

Adaptive Brake Lights
The system gives an indication to the following drivers about the strength of the braking manoeuvre. The information can be provided e.g. through variation of the area of the brake lights or the frequency of flashing brake lights. The stronger the braking is the bigger is the illuminated area or the higher is the frequency.

Obstacle and Collision Warning
Warning against imminent forward collisions without intervention.

Emergency Braking / Brake Assist System
In emergency braking situation some drivers do not activate the vehicle brake with the highest possible force to make full use of the ABS. If the special conditions of emergency braking situations are detected from some brake activation parameters the brake assist system activates the vehicle brake with the highest possible force (ABS braking).

SAFETY BENEFITS

ACC
The safety benefit of ACC arises mainly from a reduction of the number of rear-end collisions. The total effect of ACC is very uncertain. Cruise Control systems reduce driver stress but can also cause safety problems in critical situations, if not properly designed (Gustafsson, 1997). Autonomous Intelligent Cruise Control has been shown to decrease speed variability but also to reduce headways — the latter effect indicates increased accident risks. Active gas pedal control tends to increase headways indicating improved safety (CEC, 1998).

Adaptive Brake Lights
Adaptive Brake Lights are designed to reduce the risk of bumper-to-bumper collisions by enlarging the brake light area when the driver forcefully applies the brakes. Adaptive brake lights are already standard equipment for the BMW 7 Series.

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[8] http://www.gavrila.net/Computer_Vision/Smart_Vehicles/smart_vehicles.html

Obstacle and Collision Warning
Collision warning systems will gives safety benefits by alerting the driver of a dangerous situation. The effect is closely related to the ability of the driver to take evasive action.

Emergency Braking / Brake Assist System
Properly designed collision avoidance systems have the potential to contribute substantial improvements in safety. The technologies required to make collision avoidance feasible are not yet mature; the systems are only relevant to some kinds of crashes; and driver behaviour in vehicles fitted with such systems is not known.

POTENTIAL

The full potential would arise with intervening systems similar to ATC on trains. Perrett & Stevens (1996) have predicted the safety potential if anti-collision systems were introduced on 100 % of all vehicles. Anti-collision systems not only detect a threatening accident, it also changes speed or direction to avoid the accident. Both emergency braking and activation of support systems is included. The prediction is that in 20 % of all accidents on trunk roads should 80 % of all fatalities be avoided. That would imply a total effect of ca 15 % reduction of all fatalities on trunk roads. There are however many question marks around what types of accidents that such a system could prevent.

2.3 Local risk information

photo:IVSS

DESCRIPTION

Local risk information include Outside Temperature Information, Rain sensor, Extended Floating Car Data, Local Hazard Warning and Urban Drive Assistant.

OVERVIEW

High accident risks caused by adverse weather conditions or complex traffic situations can be decreased by providing information, warnings and support to road users.

Outside Temperature Information / Warning
Information to the driver about the outside temperature. This can be helpful to give some indication for the probability of black ice. If the temperature falls below a certain level a warning may be given to the driver.

Rainsensor
The system detects the amount of rain (wetness on the windscreen) with optical means. This leads to the activation and the adaptation of the speed of the windscreen wiper to the actual precipitation conditions.

Extended Floating Car Data
A vehicle has a lot information available which can be provided to a service centre, processed and transmitted with other information to the driver again. Data about location and speed variation are floating car data and can help to create actual congestion and traffic flow information. Additional data from other sources of the vehicle e.g. switched on lights, windscreen wipers on, fog lights on, information from ABS, stability control systems and others are extended floating car data, which can - after filtering - provide information about potentially dangerous situations at certain locations.

Local Hazard Warning / WLAN car2car-Communication
To transmit warnings about hazards and extended data to other vehicles in the surrounding there are some activities about technologies of wireless local area networks between cars. Vehicle can be used as sender, receiver and relay stations for that information. Other technologies using communication infrastructure can provide local hazard warnings with the help of extended floating car data too

Urban Drive Assistant
Function that supports the driver in very complex urban driving situations e.g. by traffic sign recognition when approaching traffic lights.

Safety benefits

Outside Temperature Information / Warning
Systems to warn the driver of temperatures use sensors externally mounted to monitor current road surface and air temperature. These system can prevent accidents if the driver is unaware of the dangerous road surface conditions.

Rain sensor
Safety benefits will arise if the visibility is improved and the driver not is increasing his speed too much.

Extended Floating Car Data
In modern vehicles, the data available include not just vehicle speed but also a wide variety of other variables. These can be acquired in digital form from the vehicle's data buses. With their help it is possible to develop better traffic information as temperature or rain sensor data, which contribute to increasing road safety and driver convenience.

Local Hazard Warning / WLAN car2car-Communication
It can be desirable in certain situations to be able to contact another driver near the own car e.g. to inform about a defect brake light or to inform other drivers about potential dangers as ghost riders. Safety benefits will arise if these systems assist and not distract drivers.

Urban Drive Assistant
Safety benefits will arise from better recognition of traffic signs if drivers comply to traffic rules better by being better informed.

Potential

The full potential of Local Risk Information will arise if weather related and other type of hazard information automatically were transferred to other vehicles in the vicinity. Intervening systems, which secure that the risk information is used to enhance safety, have a greater potential than informative systems.

2.4 Vision enhancement

Photo: IVSS

DESCRIPTION

Vision enhancement systems include Night Vision, Adaptive Head Lights, External Wide Angle Mirrors and Head-up Display

OVERVIEW

Night Vision
Assistance function with camera techniques like infra-red which enhances the perception of pedestrians and other relevant objects at night.

Adaptive Head Lights/ Intelligent illumination

The system consists of electromechanical controlled headlights to ensure optimum illumination of the lane in bends. The headlight is directed into the bend as soon as the vehicle begins cornering. A reduction of the glare to the upcoming vehicles is possible. The vehicle speed, yaw-rate and steering wheel angle are input data for the controller of the system. An extension is *Automatic Headlight Activation*, which automatically switches on the headlights when major environmental conditions for the use of head lights are existing.

External Wide Angle Mirrors
At both sides of a vehicle normally there are some blind spots. The wide-angle side mirrors reduce the blind spot area. If these mirrors are heated the vision in bad weather conditions are optimised further on.

Head-up Display
The head-up display provides the driver with driving relevant information in his direct field of view by projecting it onto the windscreen. The brightness of the information can be adapted to the environmental light conditions manually or automatically.

SAFETY BENEFITS

Night Vision
Vision enhancement systems could be beneficial to safety in the dark or in poor visibility. The extent of road safety impact of Night Vision will rely on how drivers will adapt their behaviour to the increased visibility conditions. Drivers have been found to compensate for the improved vision by increasing their speeds as demonstrated, for example, by Kallberg (1991).

Adaptive Head Lights/ Intelligent illumination

According to figures from Germany's Federal Statistics Bureau, more than 40 percent of all automobile accidents resulting in death occur at night, despite the fact that there is up to 80 percent less traffic on the road than during the day. The adaptive headlights use a variable headlight control system geared to the driver's position on the road. This anticipative illumination of the road ahead is based on a system of sensors and computers. The adaptive headlights direct two bi-xenon headlight modules geared to the steering to the ongoing course of the road, offering the driver a better view at the road ahead both in front and in curves. Adaptive Headlights automatically adjust the light to match the direction of travel. That enables the driver to react more quickly because he/she will see the road ahead more clearly. Sensors monitor vehicle speed and steering angles to assure the proper distribution and control of the beam pattern. An electronic control unit processes the data and activates the adaptive lighting system, which switches the headlights to full-beam, dipped or cornering settings.

External Wide Angle Mirrors

Safety benefits will arise if the number of conflicts caused by impaired wide-angle visions is reduced.

Head-up Display

The display enables a wide range of information and messages to be relayed to the driver. With this "visual information window" racing drivers can register visual information while still paying full attention to their driving. For example, the driver can be alerted to an accident on a certain stretch of the track or a patch of oil in a particular turn.

POTENTIAL

Some vision related problems are in fact caused by perception errors. The full potential of vision enhancement will arise if drivers are made aware of possible dangers by warning systems or by sensors linked to collision avoidance systems.

2.5 Lane keeping

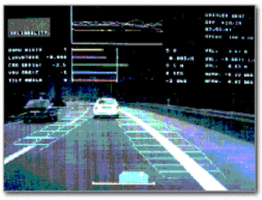

Photo: IVSS

DESCRIPTION

Lane keeping is supported by three functions: Lane Keeping Assistant, Lane Departure Warning and Lane Change Assistant.

OVERVIEW

Lane Keeping Assistent
Active lane-keeping support through additional and perceptible force in the steering wheel. (eSafety)

Lane Departure Warning
Warning given to the driver in order to avoid leaving the lane unintentionally. Video image processing is the most important technology. (eSafety)

Lane Change Assistant
System which gives information/warning to the driver about relevant obstacles when driver intends to change the lane. (eSafety)

SAFETY BENEFITS

The first two applications assist the driver in keeping the direction and contributes to the prevention of collisions where the driver for example because of tiredness slips into the wrong lane (results in worst cases in meeting accidents) or runs off-the-road (single accidents). Lane Keeping Assistant implies that the car is automatically steered parallel to the drivers steering movements, while Lane Departure Warning warns the driver by for example vibrations in the steering wheel[9].

POTENTIAL

A Lane keeping assistent can contribute to safer lane changes by warning and preventing lane changes when vehicles reside in parallel lanes close enough to constitute a collision risk. An integrated and fully automatic system may reach the full potential. Perrett & Stevens (1996) estimate that the number of accidents on motorways can be reduced by 1 %. On the whole netork the benefit may be as large as 2 %. These predictions are valid under the condition that all cars have been equipped with Lane keeping assistants. Najm & Burgett (1997) assert that the number of single run-off-the-road accidents can be halved.

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[9] Derived from IV Source webpage 2003-11-10.
http://www.ivsource.net/archivep/2001/feb/010212_nissandemo.html

2.6 Driver and vehicle monitoring

DESCRIPTION

Driver and vehicle monitoring systems include Driver Condition Monitoring, Roll Stability Control, Electronic Stability Programme, Active Front Steering and Tire Pressure Monitoring.

OVERVIEW

Driver Condition Monitoring
The system monitors the condition of the driver. Discussed parameters today are drowsiness, distraction, and inattention. (eSafety)

Roll Stability Control in Trucks
System which enhances rollover resistance of trucks by active brake intervention and/or reduction of engine torque.

Electronic Stability Programme
System which supports the driver in critical driving conditions like oversteering and understeering by active brake intervention and/or reduction of engine torque. A lot of other control systems for example ABS can be integrated in that function.

Active Front Steering
The AFS allows - electronically controlled - a variable steering transmission and steering force support. Two different inputs overlap , the steering angle from the steering wheel and a correction angle calculated by a controller.

Tire Pressure Monitoring / Runflat Indicator
In case of an air loss in a tire the systems gives a warning to the driver. With the runflat indicator the system detects the different rotation speed of the tire which is underinflated. In case of a tire pressure monitoring system the air pressure in each tire is monitored and displayed if necessary.

SAFETY BENEFITS

Driver Condition Monitoring
A relatively great number of crashes occur yearly because of fatigue or impaired driving ability. Tiredness is a contributing factor in 18 percent of all single accidents and in 3-6 percent of all fatal accidents with heavy goods vehicles. A low-cost drowsy driver monitor, the Copilot, have been developed. The Copilot consists of a digital camera integrated with a low-cost digital signal processor (DSP). The Copilot measures slow eyelid closures as represented by PERCLOS (Percent Eyelid Closure). This indicator has been separately validated in two independent laboratories as an accurate predictor of performance degradation in sleep-deprived subjects. Safety benefits will arise if impaired driving ability is effectively tracked and only limited compensatory effects can be found.

Roll Stability Control in Trucks
Stiffer suspensions, lower roll centre designs, and higher tire pressures help, but the driver is still the biggest influence on vehicle stability. Roll Stability Control Systems use information from the ABS wheel speed sensors, the throttle position sensor, steering wheel angle, steering

wheel rate of change, and a 'yaw' rate sensor that measures the change in vehicle direction. If the computer determines that conditions exist that could be a potential roll-over, the system applies one or more brakes and reduces engine torque to make the vehicle more stable. Safety benefits arise if no compensatory effects can be found.

Electronic Stability Programme
ESP means that risk of skidding is detected and brakes automatically activated for individual wheels such that skidding and lateral positioning of the vehicle is avoided.

Active Front Steering (AFS)
AFS facilitates urban driving by reducing the steering movements that is needed in low speed, such that e.g. a parking manoeuvre can be made with as little as a two third turn of the steering wheel. This may imply safety benefits for pedestrians.

Tire Pressure Monitoring / Runflat Indicator
Safety benefits will arise from a Tire Pressure Monitor if the warning is given so early that the driver can find a service station and correct the tyre pressure and reduce the risk of an accident.

POTENTIAL

The full potential of driver and vehicle monitoring systems includes efficient detection of impaired drivers and deficient vehicles. Perrett & Stevens (1996) gives 4 different examples of controls that are possible:

- The vehicle should not be used because it is in a bad condition or the driver has no driving license
- The driver drives intentionally in a speed or in a manner that constitutes a danger to other road users.
- The driver is tired or influenced by alcohol or drugs.
- The driver continues to drive in a ”normal” way despite the conditions beeing such that it is unsafe to do that.

The use of an accident data recorder (“black box”) on commercial vehicles for driver monitoring purposes resulted in a substantial reduction in accidents as well as decreasing the severity of the accidents. Driver monitoring functions on private vehicles have also indicated changes in driver behaviour which indicate improved safety, (CEC, 1998).

Perrett and Stevens (1996) estimate that driver and vehicle monitoring systems could reduce the total number of accidents by 4 per cent. Automated roadside safety inspections allow electronic access to the safety records of carriers, vehicles, and drivers in order to determine which vehicles should be stopped for an inspection. The inspection process is automated through the use of sensors and diagnostics to establish the integrity of safety related vehicular components. A large-scale introduction of the systems could reduce heavy goods transport related fatalities by perhaps 15 per cent (Evanco, 1997).

2.7 Policing and tutoring

DESCRIPTION

Policing and tutoring include Automatic speed cameras, red-light cameras and driver tutoring

OVERVIEW

Speed cameras
Hastigheten på den aktuella vägsträckan övervakas via radardetektorer. Om fordonen som passerar detektorn överskrider tillåten hastighet aktiveras automatiska kameror. Kamerorna registrerar och fotograferar föraren och registreringsskylten på den bil som kör för fort.

Red-light cameras

Radar detectors used for monitoring of red-light violations.

Driver tutoring

In-vehicle systems giving feedback to the drivers of their speed behaviour in the form of verbal messages or feedback by means of the accelerator pedal.

SAFETY BENEFITS

Speed cameras
Automatic speed cameras implies increased frequency of control and increased risk of detection for the drivers. The increased risk of detection influence more road users to adapt the speed to current speed limits, which give as well a reduction in the average excessive speed as generally lower mean speeds. Lower speed levels imply increase in road safety.

The safety benefit of autmated speed surveillance is studied by Elvik[10]. The result is based on some ten reports, of which one investigation of effects in Australia [11] seems to be most important. For all injury degrees and all accident types, the average effect of automated speed cameras is a reduction of injuries of 17 %.

Evaluations of mobile speed cameras on Valhallavägen, Huddingevägen and Nynäsvägen[12] in Stockholm also indicate positive safety effects. Average speed was reduced with 1 to 5 kph at the different locations.

Red-light cameras

Automated traffic signal compliance enforcement systems, red-light cameras, have been found to increase traffic signal compliance considerably. The overall estimate of the effect of these systems is a 12 per cent reduction in the number of injury accidents. The system has decreased especially crossing and rear-end accidents (Elvik et al., 1997).

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[10] Elvik et al. (1997). Trafiksikkerhetshåndbok. Transportökonomiskt Institutt, Oslo 1997.
[11] Cameron et al. (1992). *Evaluation of the speed camera program in Victoria 1990-1991. Phase 3: Localised effects on casulaty crashes and crash severity. Phase 4: General effects on speed*. Monash University, Accident Research Centre. Report 54 Clayton 1994.
[12] Vägverket. (2002). *Lite lugnare tempo, Lokalt Hastighetsprojekt på Nynäsvägen*. Vägverket. Rap nr 2002:0527

Driver tutoring

Drivers should benefit from feedback that informs them of the quality of their driving performance, and thus strengthens appropriate driving procedures. Tutoring systems have been tested and proved to be effective in reducing the incidence and seriousness of speed errors. Immediate feedback after the error was more effective that prospective (based on driver's own performance the last time he/she was at a similar location as the one close ahead) or accumulated feedback (based on driver's own performance across a number of trips around the test route). It is, however, possible that these systems lose their effectiveness due to the drivers considering the recommended procedures unnecessary or inefficient (Kuiken, 1996).

POTENTIAL

The full potential would arise if not only enforcement of speed and red-light violations were included in the system, but also continuous tutoring of the driver. Minor speed limit offences, red light/pedestrian light negation, non-compliance with stop signs, use of restricted lanes/road shoulders/emergency lanes, illegal movements and priority errors have been identified as suitable for driver tutoring.

2.8 Incident management

DESCRIPTION

Incident management includes the detection, warning and clearance of incidents. (ETSC). The full system includes automatic incident detection, variable message signs, in-vehicle or infrastructure-based warning-systems and highway patrols.

OVERVIEW

Automatic incident detection (AID)
AID collects and filters automatic emergency calls from sensors and detectors.

Variable message signs (VMS)
Variable traffic signs can change their information according to specific traffic situations. Variations in speed limits, routing, warnings and other congestion information help to provide the driver with necessary information for better decisions, which are adapted to the traffic situation. Control of messages can either be made manually from a Traffic Control Centre or automatically with sensors that can detect traffic and road conditions.

In-vehicle or infrastructure-based warning systems
Incident warnings available on on-board equipment as navigation systems, mobile telephones and PDA. Warning systems about incidents and dangerous situations do not necessarily have to rely on vehicle based technology. There are some solutions which are only based on the infrastructure to warn the drivers. Flashing beacons, radar based excessive speed information and variable traffic signs are examples of such systems.

Highway Patrol
System to assist the highway patrol to detect and locate incidents in order to reduce the duration and resulting delay.

SAFETY BENEFITS

Integrated incident management
Safety benefits are obtained by avoiding secondary accidents as a result of quicker incident management provided by the introduction of ITS. Incident warnings are provided by roadside VMS or beacons, and via radio and cellular information services.

Studies usually show accident reductions on the IWS (Incident Warning System) equipped motorway sections. The whole range of the effect on the total number of injury accidents is from –35 per cent to + 9 per cent, where the largest reductions may include bias caused by the regression-to-the-mean effect. The effects are more beneficial on secondary accidents (Kulmala, Fránzen & Dryselius, 1995). Very little information exists of the safety effects of radio based IWS systems such as RDS-TMC (Radio Data System–Traffic Message Channel). According to Elvik et al. (1997), rear-end injury accidents have decreased as a result of queue warning systems on motorways whereas the number of rear-end accidents resulting in property damage have increased.

Variable message signs (VMS)
An application of VMS is to inform derivers of weather condiations as slippery conditions or fog. A Finnish study (Rämä et al., 1996) showed that slippery road warning VMS decreased mean speeds by around 1–2 km/h when the signs were lit. The system was also shown to affect the direction of attention to find cues showing potential hazards, and to make passing behaviour more careful indicating an even larger positive impact on safety than that due to lower speeds (Luoma, Rämä, Penttinen & Harjula, 1997).

The automatic fog-warning system on the M25 motorway in England displays the “Fog” legend on roadside matrix signals. The assessment of this system showed that the net mean vehicle speed reduction was around 3 km/h, when the signals were switched on as a result of the formation of fog (Cooper & Sawyer, 1993). Collision warning systems are probably beneficial to road safety in the fog (Saroldi, Bertolino & Sidoti, 1997).

POTENTIAL

A necessary condition to utilise the full potential of incident management is access to automatic detection systms that can detect accidents in a few seconds, a rapid system for forwarding of information to VMS and on-board units (OBU) within a minute and an advanced rescue service (SOS) and an efficient system for evacuation (VägAssistans).

2.9 Flow control

DESCRIPTION

Flow control include ramp control (or ramp metering), lane control, route diversion schemes, and in general traffic management.

OVERVIEW

Ramp control implies utilisation of technology that vehicles are released on ramps in such a rate that the traffic on a motorway not hits the capacity threshold.

SAFETY BENEFITS

Safety can be improved not only by just reacting swiftly to incidents but also by preventing them through harmonisation of the traffic flow.

Ramp metering is mainly a measure to decrese congestion, but has also a certain road safety effect. Perrett & Stevens (1996) predict that increased attention of drivers lead to 10 % reduction of accidents at the implementation of ramp metering.

Lane control has little effect on injury accidents (Perrett & Stevens, 1996 and Elvik et al., 1997).

POTENTIAL

The full potential will be obtained with an integrated motorway control system. In this case, it is estimated that ramp control can lead to a reduction of accidents with 15 % (Lind, 1997; Perrett & Stevens, 1996 och Tarry, 1997).

2.10 Urban traffic control

DESCRIPTION

Urban traffic control includes signal control and area-wide network control

OVERVIEW

The primary tool of urban traffic control is *signal control*, which is applied in the urban network to facilitate the safety and efficiency of road transport in the network.

Network control systems vary in their context from one urban area to another, and may include incident management, traffic signal management as well as motorway control functions (Lind, 1997).

A special case of signal control is to give *priority for rescue vehicles*.

SAFETY BENEFITS

Signal control

Signal control aims at reducing crash risk by separating conflicting road user flows in time. The implementation of traffic signals at junctions has been found to decrease the number of injury accidents on average by 15 per cent at T-junctions and by 30 per cent at X-junctions (Elvik et al., 1997). It should be noted that these effects apply to junctions, which have higher than average crash frequencies. Crossing and turning accidents usually decrease the most whereas the number of rear-end accidents often increases after the implementation of signal control.

Network control

The crash risk at a signalised junction is related to the magnitude of different traffic flows, and especially turning flows at the junction. Hence, crash risk in an urban network can also be affected by combining signal control to other traffic management measures such as, for example, turn prohibitions to produce optimal routing patterns with regard to safety as well as travel times. The optimisation of network control systems in this way should decrease the crash risk in the network. A modelling study indicated that network optimisation could reduce accidents by 12 to 30 per cent while increasing total travel time by 10 to 15 per cent in a congested network (Maher, Hughes, Smith & Ghali, 1993).

Priority for rescue vehicles

Perrett & Stevens (1996) have estimated that 2 % of fatal accidents will be transformed to accidents with serious injured and that 2 % of serious accidents will be transformed to light injury accidents after implementation of the system.

POTENTIAL

The full potential will be obtained with an integrated system with advanced co-ordinated signals, area and corridor control (linked also to motorway control systems) and intelligent priority for rescue vehicles.

2.11 Vulnerable road users


Photo: SAVE-U

DESCRIPTION

Safety systems for pedestrian and cyclists include specially designed traffic signals, pedestrian reflectors, vulnerable road user and dangerous gap detection.

OVERVIEW

Pedestrian-friendly traffic signals

These systems include ITS device to detect vulnerable road users waiting to cross and crossing the road or junction (Sayeed, Kehtarnavaz, Rajkotwala and Nakamura & Urbanik, 1996).

Pedestrian Reflectors

Pedestrian protection needs information about the location of the pedestrians. If there are active or passive reflectors at the pedestrian or his clothes, there might be the possibility to enhance the detection of pedestrians.

Vulnerable road user detection

Within the EU project SAVE-U are sensors developed, that are suitable for detection of pedestrians and other unprotected road users.

Dangerous gap detection

Dangerous gap detection or is a function to support improved safety for pedestrians and cyclists in urban streets (Lind, 1997). It includes detection of dangerous combinations of speed and gap with more or less advanced technological solutions.

SAFETY BENEFITS

Pedestrian-friendly traffic signals

The main objective of these systems has been to improve the safety of vulnerable road users. These systems have been found to reduce red light violations by pedestrians and hence to have a positive effect on safety (Carsten, 1995).

Pedestrian Reflectors

More than half of all fatal pedestrian accidents occurs in darkness. The collision risk for pedestrians in urban areas is at least 2-3 times higher at darkness than in daylight. Almost half of pedestrian injuries at intersections with pedestrian crossings occur in darkness or twilight. Road traffic victims wear typically no reflectors.

The area of enlightening from dipped vehicle headlights has great limitations. A pedestrian at 50-meter distance without reflector results in a very small and blurred picture. A driver can on the other hand see a person with reflector from a distance of 200 meters by normal circumstances. A passing vehicle with head lights turned reduces this distance to ca 40-50 m. In bad weather conditions and darkness, a pedestrian can be distinguished only from a 15-20 meters distance. A person with reflectors is visible from 100-200 meters. The reaction time to avoid a collision is 1-2 seconds. A car driving at a speed of 80 kph covers 22 meter per second.

Vulnerable road user detection
Safety benefits will arise from vulnerable road user detection if it can be used to reduce speed and improve obstacle detection systems in areas with pedestrians and cyclists.

Dangerous gap detection
It has been proven by the video monitoring that the presence of free vehicles has a decisive negative influence on the pedestrian safety. A free vehicle is defined as a vehicle with a time gap of 3 sec ahead. These vehicles, which compose around 40%, account for all eleven recorded pedestrian accidents during 1991-92. It is thus important to reduce half long time gaps between the vehicles, which allure the pedestrians to take chances when crossing the street. Safety benefits will arise if dangerous gaps can be reduced or proper warnings of dangerous situations can be given for pedestrians and/or drivers.

POTENTIAL

The full potential of vulnerable road user systems will be utilised if all good ideas could be integrated in one system.

3 Reduction of crash consequences (passive safety)

3.1 Crash impact mitigation

DESCRIPTION

Active safety systems help to avoid accidents. Passive safety systems mitigate the consequences of accidents.

OVERVIEW

Crash course correction
By means of ITS the speed at the collision may be reduced and the course of collision may be changed and thereby the physical impact of the crash may be less serious. For instance the in-vehicle or between-vehicle ITS may decide that in a situation where a crash for some reason is inevitable it is less dangerous to have two single vehicle crashes at a reduced speed in a forgiving environment than a frontal collision at high speed.

Pre-Crash Activation
In the pre-crash phase when a crash is unavoidable some systems are active to prepare the configuration of passive safety systems like seat belts, seating positions and others.

This complementary security system controls, when an incident is threatening, that safety equipment as safety belts, air bags etc. are optimally adapted to the situation. If stretching the safety belt prevents an accident, passengers and drivers can automatically restore the original settings. The reversible design implies that the system immediately is ready for use again if necessary.

SAFETY BENEFITS

Crash course correction
Great safety benefits would arise if it were possible to realise the idea to predict crash consequences and select the most favourable outcome.

Pre-Crash Activation
The injury impact would be possible to reduce with ca 20 % if various ITS systems of the type ”activation of support systems” could be implemented. In this estimate is included for instance systems that monitor if the persons inside the car are using safety belts and the weight of the passengers. The function of the air bag is adapted to this information.

POTENTIAL

The full potential would arise if both these bold ideas could be realised in an integrated system.

3.2 Occupant protection

DESCRIPTION

Occupant protection systems include seat belt reminder and air bags

OVERVIEW

Seat Belt Reminder

The seat belt reminder usually consists of a warning lamp, which is switched on and in certain cases a sound that is experienced as so irritating that the driver puts on his seat belt. The more aggressive the audible and visible signals are, the greater effect has the belt reminder according to Swedish studies (ETSC, 1999). If public acceptance is sufficiently high an even better result could be reached by compulsory interlock systems. If the driver (or any passenger) not have put on his seat belt the vehicle is not possible to start or drive at anything but a very low speed.

Air bags

If crash sensors in the car detects hits that exceed the value that is needed to release the air bag the control system activates the gas generator. This unit blows up the air bag in the steering wheel and in the dashboard in front of the front seat passenger within 30 to 40 milliseconds. When these are blown up they will take up energy from the forward movement of the head and the upper part of the body and distributes the load over a much large area. Already after 120 milliseconds the air bag is emptied of air again and collapses.

SAFETY BENEFITS

Seat Belt Reminder

SNRA has found that there is a potential to reduce the number of fatalities with 80 persons per year if everyone used seat belt[13]. Safety benefits would arise if sceptical and absent-minded drivers were convinced to use seat belts with a more comfortable system.

Air bags

An air bag reduces the risk for serious head and breast injuries at collisions. For optimal protection it is necessary also to use the safety belts. The stretching function of the seat belts and the air bag cooperates in an integrated safety system.

POTENTIAL

The full potential of occupant protection systems would arise if seat belts were used by all passengers and air bags equipped for all seats. Another solution would be to make the vehicle impossible to move without activated security systems.

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[13] Downloaded from the homepage of SNRA 2003-11-17. Pressmeddelande nr 57, augusti 2003. http://www.vv.se/aktuellt/pressmed/2003/hkpress57.htm

3.3 Pedestrian and cyclist protection

DESCRIPTION

Future pedestrian protection measures will likely include extensible vehicle structures (e.g. hood, bumper), which expand during collision in order to minimize impact of the pedestrian leg or head hitting the vehicle.

OVERVIEW

The legislative arm of the EU has recognized the importance of the problem and is studying proposals for placing limits on tolerated leg- and head- impact coefficients in vehicle-pedestrian crashes at vehicle speeds of 40 km/h. The automobile industry has responded with a package of voluntary measures to improve pedestrian protection, i.e. automatic headlight activation, ABS/EPS systems and removal of rigid frames mounted on vehicle front.

SAFETY BENEFITS

The capacity of a car to limit the injury caused to a pedestrian in a collision has been the focus of a EU research and development programme over the last twenty years. Test procedures, which have been developed, are used in the present EuroNCAP (New Car Assessment Programme, 1997) international crash-testing programme in which the EU takes an active part. Test results indicate that industry has, as yet, made little progress in this area and that legislation is now required. In future, ITS may be able to contribute to reducing injury by sensing the type and position of collision about to happen and what type of vulnerable road user is involved. This creates difficult sensor problems. However, if these variables can be sensed then the protection may be tailored in such a way that the injury consequence is minimised.

POTENTIAL

In many countries about half of those injured in road traffic are unprotected road users such as pedestrians, pedal cyclists and motor cyclists. Most of these persons are injured in urban traffic situations. Studies have shown that at collision speeds above about 30 km/h the fatality probability of a pedestrian is rapidly increasing. It is also an illustration of a general safety problem in road traffic. When the variation of the size of the road users (from a heavy truck with trailer to a young pedestrian) is too large, even a modest collision may have very serious injury consequences. This problem is most pronounced in urban traffic. But the same problem exists in rural traffic.

3.4 Emergency notification

DESCRIPTION

The emergency-call gives precise coordinates of the location of an accident to the emergency services, which are responsible for the help. The service is a multi-stakeholder function of public organisations, telecom companies and service providers and car manufacturers.

OVERVIEW

When asked what kind of ITS systems drivers would like to have, one of the most common answers was emergency notification, a Mayday system (Cairney, 1995). There is today an agreement about a common European emergency telephone number. However, there is nothing corresponding for car emergencies. Due to the satellite-based GPS (Global Positioning System), manual or automatic emergency notification systems in the vehicle will be able to quickly lead the ambulance and police directly to the position of the crash. The emergency system may even automatically tell the rescue team how serious the crash is. It is well known from other studies that the time between the crash and the treatment is crucial for determine injury outcomes. Mayday systems are already available on the market.

SAFETY BENEFITS

If the rescue team, by means of ITS applications such as automatic or manual emergency notification, may know the seriousness and the character of the crash the probability of effective treatment is increased.

POTENTIAL

A Swedish physician estimated in 1991 that 50 out of 800 fatalities (6%) could be prohibited with improved emergency service at Swedish hospitals[14]. A part of this can be prohibited by faster transport from the location of the crash, the other part by improved medical treatment.

[14] Bo Brismar, Huddinge sjukhus. Svenska Dagbladet 12 april, 1991.

4 A preliminary estimate of safety potentials

4.1 Safety potentials in different problem areas

In the following table a preliminary estimate of the safety benefit potentials is made. These are based on the literature survey, a workshop and the main report[15]. We present three different estimates, which are based on the gathered information of the different ITS safety applications:

- the verified potential using only reasonable reliable studies and field tests
- predicted potential, which is identical to the total potential in the main report and
- full potential, which is an optimistic estimate, which can be used as a stimulus for further research and development in eSafety (EU) and IVSS (Sweden) programmes.

Problem area	**Per mille of road deaths**	**Verified potential Percent**	**Predicted potential Percent**	**Full potential Percent**
Speeding	200		40%	65%
Drunk-driving	160		**20%**	**55%**
Seat belt	160		50%	70%
Fatigue	100		**6%**	**30%**
Meeting	100		45%	**85%**
Pedestrian	70		60%	75%
Crossing	50		**35%**	65%
Road-holding	50		**70%**	**85%**
Road surface	50		**60%**	**85%**
Cycling	20		**25%**	55%
Distance-keeping	20		**65%**	80%
Rescue	20		40%	**50%**
General (all areas)	1000	17%		4%
TOTAL	**1000**	**17%**	**42%**	**69%**

The full potential of ITS to reduce fatalities in road traffic seems to be enormous. Here it is estimated to 69% based on the vision that human errors in the long run can be reduced by assisting systems that intervenes when the driver has lost control of his vehicle and ended up in a dangerous situation.

[15] SNRA (2003). The potential of ITS to increase road safety in the short and long run.

The problem areas where we see most good ideas are fatalities due to meeting, road-holding and road surface accidents. More problematic is it to find ITS solutions for fatalities due to fatigue, drunk-driving and rescuing. This is because it is not only road-based problem; it is also a health service problem, which also must be solved in the medical sector. The integrity problem must also be dealt with, which means that a comprehensive view would her be suitable.

Many ITS applications are still not fully developed. When we look at verified results, the potential drops to only 17%. Most of the results are given as a total figure. That explains why we have not dared to fill in a verified potential in the various problem areas. However, if we look at the potentials in the next table, we see that verified results concern mainly speed reductions and passive safety systems.

4.2 Safety potentials for different ITS functions

Safety application	**Verified potential Percent**	**Predicted potential Percent**	**Full potential Percent**
EXPOSURE			
Demand management	< 0,5%	< 0,5%	1%
Travel planning with ITS	< 0,5%	< 0,5%	0,5%
Route guidance	< 0,5%	< 0,5%	< 0,5%
Freight and fleet management	< 0,5%	< 0,5%	0.7%
Selection of road users	1%	3%	**5%**
ACTIVE SAFETY (risk)			
Speed adaptation	**7%**	**11%**	**17%**
Collision avoidance	< 0,5%	4%	4%
Local risk information	< 0,5%	2%	3%
Vision enhancement	< 0,5%	3%	**8%**
Lane keeping	< 0,5%	2%	2%
Driver and vehicle monitoring	< 0,5%	1%	3%
Policing and tutoring	3%	4%	**7%**
Incident management	< 0,5%	1%	3%
Flow control	< 0,5%	< 0,5%	< 0,5%
Urban traffic control	< 0,5%	< 0,5%	0,7%
Vulnerable road users	< 0,5%	0,8%	1%
PASSIVE SAFETY (consequences)			
Crash impact mitigation	< 0,5%	< 0,5%	1%
Occupant protection systems	4%	**7%**	**10%**
Pedestrian and cyclist protection	< 0,5%	< 0,5%	0,6%
Emergency notification	0,8%	0,8%	**1%**
TOTAL	**17%**	**42%**	**69%**

In the table above, we have presented the same result divided by type of ITS application. First, we see that there is a great potential for active safety systems in the future. The total reduction may be as high as 48%. Passive safety may give 13% in reduction and changes in exposure 8%. The most promising areas are speed adaptation, occupant protection, vision enhancement, policing and tutoring, and selection of road users.

If we look at the predicted figures, we see a somewhat different picture. The potential is 42%, from which 3% is exposure related, 31% comes from active safety and 8% passive safety. A lot of active safety ideas is depending on uncertain driver behaviour questions. If the driver is able to efficiently understand and use assist and co-driver systems then the future looks bright.

If we lastly look at the verified figures, the potential is only 17%. It's less than a fourth of the maximum potential. You find verified results concern mainly for speed adaptation, speed enforcement and occupant protection. The remaining good ideas especially concerning active safety is a big challenge to researchers, developers, politicians and car manufacturers working together to create safer transport on European roads.

5 References

BALZ, W. & ZHU, J. (1994). Nebelwarnsystem A8 Hohenstadt–Riedheim. Wirkungsanalyse. Landesamt für Strassenwesen, Baden-Württenberg & PTV Consult GmbH.

CAIRNEY, P. (1995) Consumers views of information technology based systems for passenger cars. ARRRB Transport Research Ltd, Research Report No. 277.

CAMERON et al. (1992). Evaluation of the speed camera program in Victoria 1990-1991. Phase 3: Localised effects on casulaty crashes and crash severity. Phase 4: General effects on speed. Monash University, Accident Research Centre. Report 54 Clayton 1994.

CARSTEN, O.M.J. (1995) VRU-TOO Final Report. DRIVE II Project V2005, Vulnerable Road User Traffic Observation and Optimisation. Institute for Transport Studies, University of Leeds, Working Paper 439.

CEC (1993): White Paper on Growth, Competitiveness and Employment, CEC, December 1993.

CEC (1998): Fair Payment for Infrastructure Use: A phased approach to a common transport infrastructure charging framework in the EU. White Paper COM (98) 466, CEC, July 1998.

COOPER, B. R. & SAWYER, H. E. (1993). Assessment of M25 automatic fog-warning system: Final report. TRL Project report 16. Crowthorne. 11 p.

ELVIK, R., BORGER MYSEN, A. & VAA, T. (1997). Trafikksikkerhetshåndbok (Traffic Safety Manual). Transportøkonomisk Institutt, Oslo. 704 p. ISBN 82-480-0027-3. ISSN 0802-0175.

ETSC (1999). Intelligent Transport Systems and Road Safety. Brussels, European Traffic Safety Council

EVANCO, W. M. (1997). The impact on fatal involvements of Commercial Vehicle Operation

FEDERAL HIGHWAY ADMINISTRATION (1997). Review of ITS Benefits: Emerging Successes. FHWA-JPO-97-001.

GOLDBERG, Fred (1995): Electronic Driving Licences: Key to a New Traffic Safety System. Paper presented at the 13th International Conference on Alcohol, Drugs and Traffic Safety (T'95) in Adelaide, Australia, 1995.

GUSTAFSSON, P. (1997). ISA Intelligent Speed Adaptation. Who Wants It? . Proceedings, 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin, Germany. ITS America, ERTICO & VERTIS.

ICDTS Working group on Alcohol Ignition Interlocks (2001*). Alcohol Ignition Interlock Devices I: Position Paper.*

ITS WORLD (1997) Section 6.5

KALLBERG, V-P. (1991). Reunapaalujen vaikutus ajokäyttäytymiseen ja liikenneonnettomuuksiin (Effects of reflector posts on driver behaviour and accidents). Helsinki. Tiehallitus, kehittämiskeskus. Tielaitoksen selvityksiä (Finnra reports) 5/1991.

KUIKEN M.J. (1996) Instructional support to drivers. The role of in-vehicle feedback in improveing driving performance of qualified motorists. University of Groningen. Doct. dissertation ISBN 90-6807-305-2.

KULMALA, R., FRÁNZEN, S. & DRYSELIUS, B. (1995). Safety Evaluation of Incident Warning Systems -Integration of Results. HOPES Deliverable 35.

LIND, G. (1997) Strategic assessment of intelligent transport systems — a user-oriented review of models and methods. Royal Institute of Technology, Department of Infrastructure and Planning, TRITA-IP FR 97-29.

LUOMA, J., RÄMÄ, P., PENTTINEN, M. AND HARJULA, V. (1997). Driver responses to variable road condition signs. Proceedings of the Conference on International Cupertino on Theories and Concepts in Traffic Safety, Lund, Sweden, November 5-7, 1997.

MAHER, M., HUGHES, P., SMITH, M. & GHALI, M. (1993). Accident- and travel time minimising routing patterns in congested networks. Traffic Engineering and Control, September 1993. Pp. 414-419.

MARKÖR (2000). (In Swedish) Entreprenörernas syn på alkolås, en utvärdering av alkolåsprojektet i Jönköping och Växjö. Delrapport 2.

MOCK-HECKER, R. SCHNITTGER, S. (1997): Influence of Time and Route Dependent Road Pricing Schemes on Driver Behaviour. Proceedings, 4th World Congress on ITS, Berlin, October 1997.

MYHRBERG, S. (1997) Field Trials With Electronic Driving Licence in Sweden. Proceedings, 4th World Congress on ITS, Berlin, October 1997.

NAJM, W. G. & BURGETT, A. L. (1997). Benefits Estimation for Selected Collision Avoidance Systems. Proceedings, 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin, Germany.

PERRETT, K. E. & STEVENS, A. (1996). Review of the potential benefits of Road Transport Telematics. Transport Research Laboratory, TRL Report 220.

SAROLDI, A., BERTOLINO, D. & SIDOTI, C. (1997). Driving in the fog with a collision warning system: A driving simulator experiment. Proceedings, 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin, Germany.

SAYEED, M., KEHTARNAVAZ, N., RAJKOTWALA, F., NAKAMURA, E. & URBANIK, T. (1996). A vision-based automatic push button system. Proceedings, Third World Congress on Intelligent Transport Systems, Orlando, Florida, 1996. ITS America.

SCHULTZE, M. (1997): CHAUFFEUR — The European Way Towards an Automated Highway System. Proceedings, 4th World Congress on ITS, Berlin 1997.

SNRA. (2002). Local speed reduction project on Nynäsvägen. (In Swedish) Lite lugnare tempo, Lokalt Hastighetsprojekt på Nynäsvägen. Vägverket. Rapport nr 2002:0527.

SNRA (2003a). ITS Effektsamband, uppdatering av Effektsamband 2000 med avseende på ITS. Swedish National Road Administration.

SNRA (2003b). The potential of ITS to increase road safety in the short and long run. (In Swedish). Swedish National Road Administration.

STÅHL, A., BERNTMAN, M. AND PETZELL, J. (1997). Use Of Route Guidance System Experiences Among Elderly Drivers. Proceedings, 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin.

TARRY S. (1997) The benefits of access control applied to motorway operations. Proceedings 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin, Germany.

TRAFFIC TECHNOLOGY INTERNATIONAL. Single vision. Aug/Sept 2003 p.10.

VÁRHELYI, A. (1997). Dynamic speed adaptation in adverse conditions. Proceedings, 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin, Germany.

WINKLER, R. & NOWICKI, J. (1997). Experience With The Implementation Of On-Board Navigation Systems. Proceedings, 4th World Congress on Intelligent Transport Systems, 21-24 October, Berlin, Germany.