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1.6.2: Sustainable Surface Transport

Police Enforcement Policy and Programmes on European Roads

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Innovative technology for monitoring traffic, vehicles and drivers

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ABSTRACT

Deliverable 1 “Innovative technology for monitoring traffic, vehicles and drivers” gives a broad overview of the most relevant enforcement technologies and systems used today and the potentialities envisaged for those to be deployed in the near future. Enforcement data and technological system implementations from different perspectives are presented following a structure that first classifies the technologies for their use as surveillance, monitoring and control of driver behaviour and for enforcement itself. A special emphasis is given to the possibility of relying on information systems in order to support and warn about enforcement activities. The deliverable focuses on the three main infractions highlighted by the EU Recommendations (Speed, Drink Driving and Seat Belts Use) across the road network. More thorough analysis of the effects of technologies considered particularly relevant is also provided.
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EXECUTIVE SUMMARY

Deliverable 1 “Innovative technology for monitoring traffic, vehicles and drivers” gives a broad overview of the most relevant enforcement technologies and systems used today and the potentialities envisaged for those to be deployed in the near future, mostly from a safety point of view but also taking into consideration mobility, security, and environmental improvements. Enforcement data and technological system implementations from different perspectives are presented following a structure that first classifies the technologies for their use as surveillance, monitoring and control of driver behaviour and last but not least for enforcement itself (following the steps in the enforcement chain). A special emphasis will be given to open the possibility of relying on information systems in order to support and warn about enforcement activities. The target is to approach the three main infractions highlighted by the EU Recommendations (Speed, Drink Driving and Seat Belts Use) across the road network. More thorough analysis of the effects of technologies considered particularly relevant is also provided.

Even though some of the enforcement technologies described in this paper have been proved to have a positive effect on safety, the legal/jurisdictional requirements and socio-political contexts often constitute a significant refrain to their deployment. A serious effort has to be made by EU enforcement authorities in order to provide a clear and stable legal framework, plus clear type approval guidelines in which development of new enforcement technologies can be swift and smooth among all Member States opening the possibility of cross-border solutions. The organization and cooperation of all actors involved and the consideration of interactions and synergies between automated enforcement and other ITS systems, like control and traffic information systems, together with commercial value added services, might contribute highly to their being put in operation. Furthermore, it might increase the efficiency of ITS architecture in accordance with the level of technology available in this framework while promoting user acceptance, by coming to share their same points of view thanks to the close following of actual demands.

In this context of warning, monitoring, surveillance and enforcement special consideration is given to potential integration and implication of technology across the enforcement chain. The deliverable addresses the technology development at EU level, divided in three main categories:

- ‘Active enforcement’ in accordance to the enforcement chain
- Warning/monitoring and control/surveillance technologies
- Cooperative systems.
# LIST OF ABBREVIATIONS

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<th>Description</th>
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<tr>
<td>AADT</td>
<td>Annual Average Daily Traffic</td>
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<td>ADAS</td>
<td>Advanced Driver Assistance Systems</td>
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<td>BAC</td>
<td>Blood Alcohol Concentration</td>
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<td>BrAC</td>
<td>Breath Alcohol Concentration</td>
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<td>BAIID</td>
<td>Breath Alcohol Ignition Interlock Device</td>
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<td>CALM</td>
<td>Continuous Air-interface Long and Medium range technologies</td>
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<td>CLAUDIA</td>
<td>Catching Legible vehicle data to Acquire Unlawful behaviour by Digital Information Assessment</td>
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<td>CN</td>
<td>Cellular Networks.</td>
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<td>CVIS</td>
<td>Cooperative Vehicle-Infrastructure Systems</td>
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<td>DSRC</td>
<td>Dedicated Short Range Communication Systems</td>
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<td>DUI</td>
<td>Driving Under Influence</td>
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<td>DUID</td>
<td>Driving Under Influence of Drugs.</td>
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<td>EVI</td>
<td>Electronic Vehicle Identification.</td>
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<td>FDW</td>
<td>Following Distance Warning.</td>
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<td>FIR</td>
<td>Far Infrared Radiation</td>
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<td>GIS</td>
<td>Geographic Information System</td>
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<td>GNSS</td>
<td>Global Navigation Satellite Systems</td>
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<td>HGV</td>
<td>Heavy Goods Vehicle</td>
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<td>HMI</td>
<td>Human-Machine Interface</td>
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<td>NIR</td>
<td>Near Infrared Radiation</td>
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<td>ITS</td>
<td>Intelligent Transportation System</td>
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<tr>
<td>OS</td>
<td>Operating System</td>
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<td>TMC</td>
<td>Traffic Message Channel</td>
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<td>VII</td>
<td>Vehicle Infrastructure Integration</td>
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<td>VIN</td>
<td>Vehicle Identification Number</td>
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<td>VIS</td>
<td>Video Imaging System</td>
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<td>VMS</td>
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1. INTRODUCTION

1.1 Description of work in WP3

Technology could change the nature of enforcement from primarily detection and punishment, to more prevention and self-regulation by traffic participants. Sensing, identification, location, communication, and processing technologies could assist Traffic Law Enforcement (TLE) in monitoring traffic behaviour and automatically warn or apply sanctions to offending traffic participants. Traffic surveillance and in-vehicle technologies may enable embedding of TLE elements into the routines of traffic management and in-car telematics, focussing on compliance rather than enforcement (E.g. ADAS, SpeedAlert and ISA).

The deployment of enforcement technology also requires a good administrative follow up. Technology can detect and process large numbers of violations, numbers that cannot be handled properly and in time by traditional penal law systems and manual methods. Legal support for automated processing of fines should be a priority for the promotion and deployment of these systems.

1.2 Description of Deliverable 1: Innovative technology for monitoring traffic, vehicles and drivers

The paper will address the technology development at EU level, divided in three main categories:

- ‘Active enforcement’ in accordance with the enforcement chain.
- Warning/monitoring and control/surveillance technologies.
- Cooperative systems.

Active is strictly governed by laws, laying down strict rules on type approval and certification where necessary and applicable concerning technical devices that have to measure values in relation to the violation like speeding, red light jumping, distance travelled, weight, tailgating, illegal use of bus lanes, etc.

As a brief introduction on legislation on offences for Traffic Law Enforcement in order to complete the overall description of the enforcement chain in this case, it can be said that the punishment usually follows three separate stages: detection, prosecution, sanction. Criminal law usually provides a large range of penalty types from the loss or the restriction of liberty (prison penalty), of rights (driving licence), to the financial sanction pattern (day-fine, fine-unit, fines based on the social status) or alternative solutions such as community work (day-unit).

There are some systems that are being developed and brought to the market by the industry with the aim to enhance road safety by informing and thus supporting the driver in the driving task. These are often referred to as ADAS (Advanced Driver Assistance Systems).
Other systems provide information to the driver; and they either relate to the installed infrastructure, like VMS (Variable Message Signs), or either reuse some other systems initially thought for other purposes like RDS/TMC (Radio Data System/Traffic Message Channel) or even make use of last generation tools installed in ‘smart vehicles’. This warning/monitoring technology does not always address enforcement in the first place but has the potential to inform and/or support the motorist to drive safely and in compliance with the traffic regulations. It has not punitive impacts and is voluntarily in nature, so the general increase of user acceptance on behalf of drivers should be taken into account.

Referring to the infrastructure and being more general to consider other possible applications a difference depending on the environment can be made as follows:

- Interurban Area.
- Urban Area.

In the context of this document, Interurban Area (all types of roads) includes the following enforcement practises: speed (including variable speed limits), tailgating, overtaking prohibitions, overloaded vehicles, lane closures for categories of vehicles, illegal use of the hard shoulder, road pricing, etc.

Urban Area can include the above mentioned applications and also others more specific: bus lane detection to avoid private cars transit on the reserved, lanes, restricted areas control to limit circulation to authorized vehicle only, transit with the red light at signalized intersections (that is one of the major causes of accidents in cities), parking access, etc.

The CALM (Continuous Air-interface Long and Medium range technologies) concept has been developed to provide a layered solution that enables continuous or quasi continuous communications between vehicles and the infrastructure, or between vehicles, using such (multiple) wireless telecommunications media that are available in any particular location, and have the ability to migrate to a different available media where required.

Alongside with the development of this CALM architecture it is envisaged the potential to give support to Intelligent Co-operative Systems that are based on Vehicle-to-Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications. CALM Service Types fall into two categories: safety and commercial, although some safety related services are of commercial interest as options on up market vehicles. These added value services, and given the considerable improvements expected in terms of safety and efficiency, can constitute one of the main promises in order to increase the acceptability of enforcement by public opinion.

Intelligent Co-operative Systems increase the “time horizon”, the quality and reliability of information available to the drivers about their immediate environment, the other vehicles and road users, enabling improved driving conditions and thus leading to enhanced safety and mobility efficiency. Similarly, Co-operative Systems offer increased information about the vehicles, their location and the road conditions to the road operators and infrastructure, allowing optimized and safer use of the available road network, and better response to incidents and hazards.
Legal frameworks, privacy issues, user acceptance, type approval of enforcement equipment, specification of data for describing the event, certification, interoperability, cross border implementations, benefits after implementation and collateral effects (cost effectiveness, mobility, environmental aspects) are issues to be considered and given further thought in the document.

**Three-level classification framework**

Three main domains will be covered, mirroring the infractions highlighted by the EU Recommendations (EC, 2004).

- Speed
- Drink driving
- Restraint domain

Further classification of technologies is possible taking into account the chain of enforcement, as some technologies are distinctly tailored at specific steps, detection of speed infractions being the typical case.

However, as technologies in the context of automated enforcement, have developed vastly more in the field of speed enforcement than in any other field, this third level classification will only be made in the case of Speed Active Enforcement. It is important to stress the fact that even then, some of the lessons resulting from the studies carried out in that particular field can be applied to other infractions, as will be pointed out throughout the document.

Taking advantage of the latest developments in automated speed enforcement technologies and implementation strategies, two thorough studies on particular enforcement systems will be provided, on which a selection and rationalization of the results will be provided.

1.2.1 **Methodology**

The variety of technologies available, from tried and true though limited applicability ones to incipient promising and wide applicability developments, has caused the research and writing approach of this Deliverable to be an eclectic one.

In this context of warning, monitoring, surveillance and automation of enforcement chain a special consideration will be given to potential integration and implication of technology in all this ITS framework.

The three main parts of this documents are:

**PART I: ‘Active enforcement’ in accordance with the enforcement chain:**

- Technologies for data acquisition step: Monitoring with cameras and data security and integrity in transmission across the enforcement chain (digital signatures and encryption). Use of digital video or mature communication systems (DSRC: Dedicated Short Range Communication Systems).
Technologies for secure storage and transfer of information. Again the above presented communications systems based on unwired (microwaves at 5.8GHz that is, DSRC and also infrared), or wired possibilities (i.e., fibre optic) depending on connecting sites. Even supporting the use of last generation unwired communications that open solutions regardless the specific type of data or environment changing from one media to another (GNSS/CN based systems: Global Navigation Satellite Systems/Cellular Networks, etc). This gives open vision for CALM.

Examples for key infractions (speeding, drink driving and restraints)

**PART II: Warning/monitoring and control/surveillance technologies.**

Information and warning and/or enforcement? More emphasis in the former *(Variable Message Signs VMS, Radio Data System Traffic Message Control: RDS/TMC)* together with safety campaigns and type approval of systems for allowance of flow of information between applications that serve one purpose or the other (feedback). Surveillance and deterrence effect in the drivers.

ITS in the vehicle: The use of control systems giving some autonomy to the driver and alleviating punitive related work (from ACC, *Automatic Cruise Control*, to ISA, *Intelligent Speed Adaptation*)

Examples for key infractions (speeding, drink driving and restraints)

**PART III: Cooperative systems:**

Enforcement as one of the working applications in a cooperative systems framework (CALM architecture).

Deployment of enforcement within ITS architecture using communications like V2V (GNSS/CN, Wifi), and exploiting V2I under performance as much as possible (maximizing efficiency). This would offer – for the first time – new ways for drivers and their vehicles to interact (and not just react) with a more intelligent infrastructure.

The consideration of value added services (navigation systems thanks to envisaged GALILEO and cellular networks based on 3G mobile like *GPRS* *(General packet Radio Service)*, the use of Internet).

As the document developed, and the three-level classification had been decided, gaps in the information provided by the partners were detected, and therefore an additional literature study was conducted, both on finished EU projects as well as on literature publicly available from traffic authorities from several Member States.

In the last case of cooperative systems and CALM, the results obtained until now in open projects (Example of CVIS, SAFESPOT, COOPERS, SEVECOM were considered and thus integrated in the document).
1.2.2 Objectives

The objectives of this document are, therefore:

- To provide a clear, ordered and comprehensive overview of the main technologies and technological implementations used today in the field of enforcement taken as a widest concept as possible.

- To give an outlook of the upcoming technologies that will most probably be a part of the enforcement world in the short-term.

- To present the upcoming possibilities of Cooperative systems with the envisaged CALM architecture. These offer the potential to reduce these impacts by creating additional effective road network capacity and a more efficient utilisation by vehicles.

- To increase user acceptance by first time offering of new ways for drivers and their vehicles to interact (and not just react) with a more intelligent infrastructure and provide them added value services.

- To justify the need of a common framework on which to develop enforcement technologies as we move towards a EU-wide traffic enforcement scenario laying the basis of cross border enforcement.
2. General lessons on technology

The simpler, the better

The probability that a system is delivered on time and within budget appears to be inversely related to its technological complexity. Use of “tried and true” solutions was considered integral to the success of several traffic management related projects in Switzerland and Austria, for example.

Most simple systems can be upgraded later

It is nearly always possible to start with a very basic level of technology and then upgrade to a more complex system later. This may prove particularly useful when considering the use of one particular technology such as GPS positioning, which could be initially implemented with a coarser accuracy and as technology evolves, making use of finer resolutions it might provide.

Greater complexity increases the potential for technical difficulties

One German traffic related project with similar goals to those of Switzerland and Austria mentioned before was altogether more ambitious, and looked at integration of two different technologies not tested before. As technical difficulties arose during the development phase, budget was overrun and implementation was delayed over one year.

Fallback plans ease implementation

Using the same German example as in the previous point, the premature discontinuation of the previous system while the new one was facing delays with no backup plan, left Germany with no coverage for the sector both systems aimed at for that year.

Standardization has yet to be achieved

So far, each EU country has developed and used its own solutions to the traffic problems considered, with none or little collaboration even with surrounding countries. To facilitate future interoperability between adjacent jurisdictions, some effort is needed to develop common standards. Information and communication technologies standards that apply in this case are those related to Intelligent Transport, but also those that consider data protection, network and information security issues due to the importance of making use of personal information. In any case it is quite likely that a movement toward standards will occur only after the different approaches have been in operation for some time, and their relative advantages and disadvantages have become more apparent.

2.1 Additional considerations on technology

The problems addressed are viewed as pressing

To garner sufficient public acceptance and political willpower for change, successful implementation of enforcement strategies have in all cases to address clear and widely
recognized problems that: (1) are considered important by a majority of voters (people) and elected officials (proper authorities), and (2) have not been solved through existing solutions.

The enforcement solutions produce demonstrable results

One of the biggest popular criticisms of new enforcement systems has been the idea that the revenues which a more extensive and strict enforcement produces through fines are mostly retained by enforcement and local authorities. Explicitly linking both enforcement benefits per se and the revenues they may generate with widely desired benefits, such as improvement or maintenance of transportation infrastructures, improved transit service, etc. may be the way to overcome this.

The enforcement solutions are integrated with complementary measures

Support for enforcement equipment solutions for themselves can be weak. On the other hand, they tend to be viewed much more favourably if they are a part of an integrated package that includes altogether other measures to address the problem. Marketing and education campaigns, as well as an obvious involvement of several public organizations and an improvement of the infrastructure, for example, are key elements which are to be seen together within the overall enforcement strategy.

The enforcement solutions are user-friendly: easy, reliable, and unobtrusive

Enforcement equipment can be seen from many different points of view. The term users in enforcement can apply to the driver being monitored (or whose infraction has been detected, or who received a notification to pay a fine) or the desk enforcement officer who is in charge of looking over the plate recognition software. Whoever the user, nonetheless, use and maintenance of enforcement equipment (for authorities’ staff) and the procedures when a touch with enforcement is necessary (for drivers) have to be equally user-friendly.

Additionally, when considering in-car enforcement technologies, as it is a fact that many drivers feel strongly about vehicle aesthetics, system designers have to ensure in-car technologies can be mounted unobtrusively.

Reliability of any enforcement technology has to be beyond any proof, as the credibility and therefore the acceptability of the whole enforcement system is at stake.

Strategies deriving from the systems used are to be effective and transparent

Clever users quickly find loopholes and enforcement weaknesses in any program. Successful enforcement strategies require widespread belief among the participants that cheaters are rare and will eventually be caught.

The legal framework for the enforcement needs to be clear and well-established

A diffuse legal framework can complicate the debates over local technical proposals and lead to delays in implementation. As an example, unresolved legal questions were cited as problems with toll charging projects in Scotland and Switzerland.
PART I: ENFORCEMENT
3. **Overview of traffic enforcement systems**

Active enforcement covers the strategies used by the public administrations and state-sanctioned private enforcement agents, of repressive and punitive nature, laid down on a motorist beyond his control.

From the technical point of view, it is possible to view enforcement as a series of stages, in which different technological opportunities might be used, some of them particular to one of those stages, and some others with a broader scope, which may be used as supporting technologies for the whole chain, or at least in several of the stages.

An extremely simplified enforcement chain description would include:

- Detection of the infraction
- Identification of the violator
- Notification and follow-up procedures

And although not specifically mentioned, data transmission and communications between the listed enforcement stages require a close look, as careful design must be put into legal evidence data transmission.

In this chapter the enforcement procedure will be presented as the process that follows the steps involved in the enforcement chain. On this purpose, the first step will be to define this procedure, then give a brief specification of possibilities in terms of technology for specific phases and some other aspects in relation with requirements (security, data privacy).

Finally, a wide range of examples and implementations in other countries and results from other projects will be included as examples in order to illustrate the state of the art in Europe, also trying to give an introduction that can serve as a starting point to evaluate the impact of deploying specific solutions for the key applications that, as said before, try to avoid those that have been presented as most risky infractions.

A distinction will be made between technologies for the data acquisition step and secure transmission of information mainly.

### 3.1 Definition of enforcement chain

A further description of the enforcement chain can be presented by means of the following procedure (in which some of the steps can be skipped depending on the specific cases) and accompanying diagram:
**Detection**

Detect an event and trigger the capture of all data necessary to describe the event in accordance with defined, measurable detection criteria.

- Detect measurable events
- Trigger capture

**Capture**

Capture all data required to uniquely define an event.

- Make record
- Uniquely relate record to event

**Store**

Conditioned and controlled storage, retrieval and deletion of a record.

- Define access to record (store)
- Define the levels of authorisation and define who currently holds each level of authorisation.
- Store record
- Conditioned and controlled retrieval and deletion
- History of record store

**Transfer**

Transfer a record of an event.

- Format record for transfer
- Transfer record
- History of record transfer

**Process**

Process a record of an event in order to determine all necessary data to enforce the law in question should the event constitute a violation.
Define access to record
Ascertain whether or not an event is a violation and verify in case of affirmative
Vehicle owner and/or driver data
History of record processing
Preparation of notification documentation for driver or owner and legal services involved.

Notification
Communication of the results of processing phase to all relevant parties.

There are technologies involved in the data acquisition step: Monitoring with cameras and data security and integrity in transmission across the enforcement chain: digital signatures and encryption). Use of digital video or mature communication systems (DSRC: Dedicated Short Range Communication Systems) or even the exploitation of both of them for more robust and secure procedures.

Technologies for secure storage and transfer of information. Again the above presented communication systems based on unwired or wired possibilities, depending on connecting sites. Even supporting the use of last generation unwired communications that opens up solutions regardless the specific type of data or environment changing from one media to another (GNSS/CN based systems: Global Navigation Satellite Systems/Cellular Networks, etc) . This gives open vision for CALM.

3.1.1 Data acquisition step

As technologies for data acquisition step it should be emphasize the open possibility of monitoring with cameras and the importance, in accordance with legal and privacy restrictions, the need of guaranteeing data security and integrity in transmission across the enforcement chain. For a general case of a register of information that includes the necessary data to describe the event:

Digital signatures and encryption:
In this line, the possibilities of guaranteeing data protection by means of an electronic fingerprint should be evaluated, given this is considered to be a reliable security technique in the information technology world for certification purposes. This tool does not only guarantee the authorship of the data as a handwritten fingerprint, but also its integrity.

We propose as best option the use of an advanced electronic fingerprint, as it permits to verify the source and the integrity of the messages interchanged through the communication network and allows for repudiation avoidance when necessary by means of electronic dates. Depending on the country the use of digital signatures is regulated by means of the corresponding Law.

In addition, the inclusion of some encryption mechanism in the information structured in a register previously to its storage in the equipment installed in situ should be considered. It must be said that in order to guarantee the security and integrity of the data this register must not be
decrypted until reception. Some possibilities are: symmetrical encryption systems (DES), asymmetrical encryption systems with public key (RSA), etc.

Besides this, the convenience of using digital video or keep alive mature communication systems (DSRC: Dedicated Short Range Communication Systems) should be evaluated or even the exploitation of both of them for more robust and secure procedures, or depending on the requirements and restrictions for each case.

3.2 Technologies for secure storage and transfer of information

Also referring to a much generalized case, it should be mentioned that the above presented communication systems are based on unwired (microwaves at 5.8GHz that is, DSRC and also infrared), or wired possibilities (i.e., fibre optic) depending on connecting sites. Even supporting the use of last generation unwired communications that open up solutions regardless the specific type of data or environment changing from one media to another (GNSS/CN based systems: Global Navigation Satellite Systems/Cellular Networks, etc). This will give an open vision introducing the cooperative framework in the envisaged architecture of CALM.

In the remaining of the present chapter of this paper, a description and analysis of the technologies used in the field of active enforcement, with a particular focus on the three main infractions pointed out in the EC Recommendations will be given.

As said before, the fact that the developments of technologies and complete implementations in the particular field of speed enforcement has allowed a more thorough analysis than for some of the other infractions. The third level classification in enforcement chain steps is possible, as it is the study of two real-world implementations, with a short description and an analysis of the system.

This approach is not possible in the case of the other infractions, where preliminary conceptions of technologies or ongoing projects have been included to be considered promising towards the short term future of enforcement.
4. Some specific developments for the target infractions

4.1 Speed

Speed enforcement across Europe is quite well established; as the VERA1 project pointed out, automated speed enforcement is allowed by law in the EU Member States.

Specific Camera safety programs have been established in several Member States as well, notably the UK Speed Camera program and the French automated speed enforcement program, introduced in 2003, have become quite known.

Latest development is the application of average speed enforcement systems (also known as section control enforcement systems), measuring the average speed on a stretch of road. These systems are already operational in The Netherlands and in Austria. Austria specifically applies average speed enforcement in their tunnels; this has improved tunnel safety and road safety quite considerably. It is piloted in the UK, France, and Spain. Other Member States that have plans to take up average speed enforcement are Belgium and Switzerland (putting the priority first on tunnel safety as well).

Getting ahead of some of the main results that the reports on these systems reveal, the main fact is that operational results from The Netherlands prove that the system is highly effective and efficient. It operates 24 on 7 and the percentage of violators dropped to 1 or 2 % only.

Details of some of these systems will be given afterwards, but first some general considerations on speed enforcement will be presented.

4.1.1 PACTS Research briefing on speed camera myths

One of the oldest and most criticised camera speed enforcement program is the UK program. Over time a number of critical reports in the media branded speed cameras as a “failure”. The Parliamentary Advisory Council for Transport Safety (PACTS) reviewed and analysed 10 of these criticisms and published its findings in its December 2003 Research briefing: Speed Cameras, 10 criticisms, and why they are flawed (PACTS, 2003).

As this review of research evidence indicates, excessive and inappropriate speed is a major contributing factor to road crashes and casualties. A comprehensive approach to speed management remains central to the continuing drive to reduce death and injury on our roads.

Speed cameras have proven to be an extremely successful element of an integrated speed management strategy, and studies have consistently shown that deaths and serious injuries have been reduced by over a third at speed camera sites. In this context, it is important to dispel some of the myths about cameras. Rather than ‘punishing motorists’, speed cameras may instead save the lives of motorists and other road users.

As these criticisms could be applied elsewhere in Europe as well, the full text of this PACTS report are annexed to this deliverable (Annex 1).
4.2 Detection technologies

The basic technologies that have been used for detecting speed infractions are:

4.2.1 Radar and Laser

In use for quite a long time both in manual and automatic speed enforcement systems, equipment design requirements, as well as testing, maintenance, and similar procedures are extensively documented in the respective states’ enforcement legal framework.

Apart from the usual configuration of Laser detectors, other ones have been tested, as it is the case with the scanning laser. In contrast with traditional use of a laser gun, the scanning laser is focussed vertically down on the roadway, and scans with a high frequency across one or two lanes, detecting vehicles breaking the laser beam. Based on the reflected laser beam, the system computes speeds and following distances as well as width and length of vehicles if needed.

4.2.2 Roadway Cables

- Inductive loops in pavement
- Pneumatic tubes across the road
- Piezoelectric cables

For mobile automatic enforcement of speed, some systems use pneumatic cables (rubber tubes) across the road, for example the Speed Guard system by the South-African company Trans-Atlantic Equipment.

For stationary automatic enforcement of speed, on the other hand, cables in the pavement, either inductive loops or piezoelectric (“weigh-in-motion – WIM”) cables, are preferred. The advantage of WIM cables is that they can be used for detecting both speed, following distance, and weight, whereas the inductive loops, although well suited for speed measurements, cannot measure weight, and they are less accurate than WIM cables for the measurement of following distance.

4.2.3 Optical sensors

Optical sensors are used to some extent as well. A system that is used extensively in Israel for automated speeding and headway enforcement is based on the reflection of infrared beams from special reflectors in the roadbed. A detector records when a passing vehicle crosses the beam, and record speed and headway. A video image is used for identifying the vehicle.

4.3 Detection and Identification technologies

The following two technologies have developed greatly in recent times, and their full potential is yet to be completely uncovered, though successful traffic charging and enforcement projects based on these technologies have been in use for some time.
It is worth noting that, in this differing from the previous detecting technologies, both video processing and in-car electronic equipment are not limited to detection of speed infractions, and depending on the particular implementation, they both can be used also for identification purposes, and, in the case of in-car electronic tags, include transmission or even infraction charging or billing capabilities.

4.3.1 Video image processing

Relying on a digital video camera and the appropriate video processing, video image processing has already proved to be an extremely versatile tool for detecting a number of different violations, and supplemented by any of the speeding detecting technologies mentioned before, to provide a perfect substitute for traditional still photo based spot speed enforcement equipment.

However, the true potential of video image processing lies, as said before, in both its capabilities to detect infractions other than speeding or speeding along a road section, such as illegal overtaking, illegal use of dedicated road lanes, improper use of restraint systems, etc., plus additionally facilitating the automated identification of the offending driver.

Identification of offending vehicles – and therefore owners/drivers- using video image processing is called Automatic Number Plate Recognition (ANPR) and it is described in more detail in chapter 13 (p. 99).

4.3.2 In-car electronic tags

This double-function can be equally performed by in-vehicle electronic transponders, which in principle and theory – and practice – can be used for identifying a vehicle’s position at any time, with unlimited possibilities of automatic surveillance.

In addition, the fact that this on-board unit could be developed to monitor any given parameter of the driving behaviour – speed, distance travelled and for how long, weight, (with some imagination) number of people aboard, whether driving lights or the seat belts are used, etc. – and, if communicating with external on-site beacons, to properly compare the environment circumstances with the driving behaviour opens – excessive speed when driving in a congested area, or in unfavourable weather conditions – as said before, unlimited surveillance options.

A particular implementation of this unit may be used to avoid the legal problem that arises from the fact that in many EU Member States, it is the driver who is responsible for offences committed, so issue of a legally valid infraction notification requires the identification of the driver.

This is usually made using a picture, but then, both privacy issues, as well as the more delicate subject of people being taken pictures by enforcement authorities before it is even proven that any offence has actually been committed – as it happens for example with road section average speed control systems – have hampered development of these enforcement systems.
Now, with in-car electronic devices, it may be possible to prevent the engine start unless the driver’s smart-card is inserted into the system, thus providing a reliable identification procedure, with no need of taking photos.

The usual communications technology used together with electronic tags is microwave based and called DSRC (Dedicated Short Range Communications) system, described also in more detail in chapter 12 (p. 85).

### 4.4 Spot speed automated enforcement

#### 4.4.1 General background

Spot speed automated enforcement systems have been used to record speeding in several countries for quite a long time, and are still widely used (figure 2). The acceptance of spot speed enforcement legal framework and technologies involved are unparalleled when talking about any other enforcement system.

The basic idea behind spot speed recording is that a device measures the speed of a passing vehicle and determines whether an infraction has occurred. If it is the case, a camera takes a picture of the offending vehicle – the particular picture requirements depending on the legal requirements of the given state concerning legal validity of evidences – and the associated equipment performs any additional operations necessary to produce the legally valid evidence of the violation committed.
For the purposes of measuring the speed of the passing vehicle any of the aforementioned detection technologies may be used, and whereas roadway cables are primarily used in Norway, radar technologies are preferred in Spain, for example.

Regarding image processing, there is usually none involved, except ensuring that the picture taken has enough quality to serve as court evidence.

A final word concerning spot speed systems is that it usually happens that the number of places where a camera is presumably installed – speed camera sites – is slightly larger than the number of cameras themselves. Since the motorist does not know whether a camera site is actually active or not, most of the behavioural effects of the system apply to the camera sites as well as to the cameras.

In the following pages, a particular spot speed system will be briefly described and analyzed, as many of the facts and study results are extensible to any other such system anywhere else in the EU.

4.4.2 Some implementation details

As an enforcement system, selecting the appropriate location of sites is capital with spot speed equipment, though arguably not enough care has been put to the subject of location until recently, this being for a number of different reasons which fall outside the scope of this deliverable to explain.

Spanish enforcement authorities have recently agreed in the installation of 68 new speed cameras, to be randomly placed in any of the new 175 camera sites to be also implemented (DGT, 2007). The total number of camera sites thus amounts to over 300, with plans to reach 500 fixed speed camera sites in 2008.

Criteria for selection of speed camera sites locations differ just minimally from one country to another, but the later trend is to put them in places particularly conflictive as far as speed and accidents are concerned.

These criteria are in Spain, for example:

- Black points or road stretches singularly noticed by a high accident rate in which speed appears as the main factor
- Particularly conflictive points or stretches, such as crossroads, tunnels, or road sections with a high traffic density and/or high proportion of heavy goods vehicles (HGV)
- Secondary roads where mobile speed enforcement is not possible

Taking another example, in Norway these criteria are:

- Accident frequency – the mean number of accidents during the last four years must be higher that the mean number of accidents for comparable road sections
Accident severity – at least 0.5 accidents with personal injuries per year, based on the mean number of accidents with personal injury during the last four years

Speed level – the mean speed (measured as the mean speed during one week) must be higher than the speed limit

In addition, the Road Authorities also intends to place speed cameras in roads sections where the potential of very severe accidents are present, like in tunnels.

In recent times, development of digital cameras has led to a progressive substitution of the film cameras traditionally used for enforcement for the newer digital devices. There are a number of advantages of using digital cameras instead of film cameras, such as digital devices eliminating the need of manually removing the media from the camera site and replacing with a new film, as digital cameras allow the instantaneous transmission of data to the authorities, or in a more technical aspect, allow for an easier and more seamless post-processing of the data, when necessary.

4.4.3 Analysis of the spot speed enforcement systems

Information on the impact of speed cameras over the driving speeds and other aspects of driving behaviour are insufficient. Here we will describe the results of a study commissioned by the Norwegian Ministry of Transport and Communications and the Police Directorate to TØI in 1999 to evaluate these effects of speed cameras (Ragnøy, 2002).

In consultation with the Norwegian Public Roads Administration, three road sections were selected and speed and traffic density and characterization analysis carried out for some time before and after speed cameras were installed. Data collection continued at two sites to address the longer term effects of the speed cameras, while section controls in similar road stretches that had no cameras installed were also analyzed for changes in driving behaviour that could have been produced by causes other than the installation of the speed cameras.

The following road sections were selected:

**Section 1: E6 Østfold**

This is an 8.4km road section, a two lane road with a speed limit of 90km/h and an annual average daily traffic of around 10,000 vehicles per day. 10 speed camera sites distributed with 5 in each direction of travel were installed in the end of 1999/2000. (At two sites, the data was however insufficient and could not be used).

**Section 2: E18 Østfold**

This is a 10.8km road section on a two-lane road. A total of 10 speed camera sites were installed in 1999/2000, of which six were on a road section with an 80km/h speed limit. (At one of the sites with an 80km/h speed limit, the data was inadequate and could not be used.) The speed limit was 70km/h along the rest of the road section. The annual average daily traffic was around 10,000 vehicles per day. Speed was also measured in both directions of travel at one site between the speed camera sites.
Section 3: E6 Hedmark

This is a 26km road section. 4 speed camera sites were installed in 1999/2000, in 3 of which the speed of traffic from Oslo was measured. (At one of sites measuring traffic from Oslo, the data is insufficient and cannot be used). The annual average daily traffic is around 10,000 vehicles per day, on a two-lane road with a speed limit of 90km/h. Speed was also been measured between the speed cameras, as well as at 4 sites between 7 and 19km further on (in the direction of traffic) after the speed cameras have been passed.

4.4.3.1 Effects on speed

4–6km/h average speed reduction at sections

Table 1 shows the weighted results of the effect of the speed cameras on three road sections, by direction of traffic and speed limit. Although there are variations depending on the particular control site, the trend is clear towards a speed reduction in all camera sites.

Table 1. Measured and calculated changes before and after the installation of speed cameras at the three camera sites

<table>
<thead>
<tr>
<th>Speed limit</th>
<th>Traffic direction</th>
<th>Number of sites</th>
<th>Number of vehicles BEFORE</th>
<th>Average speed BEFORE</th>
<th>Number of vehicles AFTER</th>
<th>Average speed AFTER</th>
<th>Difference comparison</th>
<th>Calculated net effect of sites</th>
<th>Calculated net effect of cameras</th>
</tr>
</thead>
<tbody>
<tr>
<td>E6 90 km/h</td>
<td>Oslo</td>
<td>4</td>
<td>1,586,944</td>
<td>85,72</td>
<td>3,070,893</td>
<td>80,61</td>
<td>-5,11</td>
<td>-1,28</td>
<td>-3,83</td>
</tr>
<tr>
<td></td>
<td>Sverige</td>
<td>4</td>
<td>1,544,490</td>
<td>89,37</td>
<td>3,411,744</td>
<td>83,32</td>
<td>-6,05</td>
<td>-1,31</td>
<td>-4,74</td>
</tr>
<tr>
<td></td>
<td>Sum</td>
<td>8</td>
<td>3,131,434</td>
<td>87,52</td>
<td>6,482,637</td>
<td>82,04</td>
<td>-5,48</td>
<td>-1,30</td>
<td>-4,18</td>
</tr>
<tr>
<td>E18 80 km/h</td>
<td>Oslo</td>
<td>2</td>
<td>327,624</td>
<td>74,24</td>
<td>169,530</td>
<td>68,88</td>
<td>-5,36</td>
<td>0,26</td>
<td>-5,62</td>
</tr>
<tr>
<td></td>
<td>Sverige</td>
<td>3</td>
<td>517,687</td>
<td>75,58</td>
<td>314,234</td>
<td>69,87</td>
<td>-5,71</td>
<td>0,11</td>
<td>-5,82</td>
</tr>
<tr>
<td></td>
<td>Sum 80</td>
<td>5</td>
<td>845,311</td>
<td>75,06</td>
<td>483,764</td>
<td>69,52</td>
<td>-5,54</td>
<td>0,19</td>
<td>-5,72</td>
</tr>
<tr>
<td>E6 90 km/h</td>
<td>Oslo</td>
<td>2</td>
<td>386,804</td>
<td>65,11</td>
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<td>60,65</td>
<td>-4,46</td>
<td>0,26</td>
<td>-4,72</td>
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<tr>
<td></td>
<td>Sverige</td>
<td>2</td>
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<td>66,97</td>
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<td>61,72</td>
<td>-5,25</td>
<td>0,11</td>
<td>-5,36</td>
</tr>
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<td></td>
<td>Sum 70</td>
<td>4</td>
<td>771,594</td>
<td>66,04</td>
<td>584,515</td>
<td>61,19</td>
<td>-4,85</td>
<td>0,19</td>
<td>-5,04</td>
</tr>
<tr>
<td>E6 90 km/h</td>
<td>Oslo</td>
<td>2</td>
<td>1,524,431</td>
<td>89,06</td>
<td>1,447,722</td>
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<td>-5,88</td>
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<td></td>
<td>Hamar</td>
<td>1</td>
<td>525,196</td>
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<td>1,76</td>
<td>-6,28</td>
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<td>84,62</td>
<td>-4,73</td>
<td>1,43</td>
<td>-6,16</td>
</tr>
</tbody>
</table>

Speed cameras effects in speed reduction in space

A speed profile is defined as a graph where speed is shown as a continuous function over a given road section. In order to portray a speed profile, continuous speed measurements are necessary. The automatic average measurements were therefore strictly speaking not adequate to portray this, since we do not know the speed between the measurement sites. Nonetheless, in order to illustrate the longitudinal speed variation in the two directions of traffic this has been done, although with some reservations.
Figure 3 shows the results from all measurement sites on the E18 Østfold. The upper part of the figure concerns the traffic direction from Sweden and the lower from Oslo. The horizontal axis shows the names of the measurement sites (the axis is not to scale). The vertical axis shows the average speed in km/h. The black curve shows the average speed after installation of speed cameras, while the grey curve shows the average speed before installation, adjusted for changes in the comparison sites. The distance between the curves in each site represents the calculated net effect of speed cameras.

All the sites named in the X-axis in the figure have cameras except Knapstad. Thus it can be seen that even though speed reduction is not as big in places where drivers know there is no speed camera, there is still a reduction, which is an important effect, considering that the Knapstad measuring spot is 3250m and 4750m past the previous camera site depending on the traffic direction.

Analysis on other road sections included in the study shows similar results, with greater speed reductions at camera sites than along uncontrolled sections, but always with a speed reduction all along the section, even at distances as long as 18km after camera site.

**Figure 3. Speed profiles at the E18 Østfold road section.**  
(Source: Ragnøy, 2002)

### Speed cameras effects in speed variations in space

From the analysis of speed profiles over the three sections, it results that the calculated changes in speed longitudinally are greater at the speed camera sites than at the measurement sites between and after speed camera sites. It can therefore be claimed that speed cameras contribute to increased longitudinal variation in speed on the road sections studied. That is, drivers increase and decrease their driving speed more in the presence of speed cameras than along a road where they know there is no speed camera.

But even though speed cameras contribute to this increased variation in driving speeds, it can not be concluded that road users compensate for the reduction in speed at speed camera sites by increasing driving speed between or after the speed cameras. As it was said in the previous point, speed cameras have led to reductions in speed at all sites where measurements have been taken.
**Speed cameras effects in the long term**

At the speed camera site at Skavabakken E6, Hedmark, speed measurements were taken 0.5 years and 1.5 years after the installation of the camera. 0.5 years after the installation of the camera, a reduction of 8.3Km/h was registered, while after 1.5 years, this reduction was measured at 8.15Km/h from the original figure before the installation of the camera, showing that the effects of the camera of average speed is stable over time – it has a lasting effect.

### 4.4.3.2 Effects on accidents

In 1996, Krohn concluded that the number of injury accidents had been reduced by 26% on Norwegian road section were speed cameras had been installed. This analysis did, however, not take the so-called “regression-to-the-mean” effect into account. Elvik (1997) did a re-analysis of the data taking this effect into account, and estimated that the number of injury accidents had been reduced by a 20% (the number is statistically significant at a 5% level).

A meta-analysis of the Norwegian studies as well as studies from other countries estimating the effects of speed cameras on accidents has shown a statistically significant effect of speed cameras on accidents. In the Traffic Safety Handbook (Elvik & Vaa, 2004), the studies are summarised, and it has been concluded that there has been a total reduction in the number of injury accidents of 17% on road sections using speed cameras. Separating between speed cameras located in urban vs. rural areas, the results showed that the reduction in all types of accidents was 28% in urban areas and 4% in rural areas. Both effects were statistically significant.

### 4.4.3.3 Cost-benefit analysis of the system

It is important to note that the following figures are given based on Norwegian spot speed systems, and therefore some care may be necessary when trying to extrapolate these results and analysis to other states. However, it is to expect that the main result, that is, that spot speed systems’ cost-benefit balance is positive, is equally valid in other countries.

In the year 2006, the cost of one digital camera including software and flash was 40.000€. The cost of constructing a speed camera site (camera box without camera, detecting devices, mains supply, etc.) is estimated to be 11.000€. In sum, the total investment cost of constructing a fully operative, digital speed camera point is 51.000€ (Statens vegvesen 2006).

Based upon information given by Krohn (1996), Elvik (1997) calculated the average annual costs for the public budget for a typical speed camera section of a road to around 31.250 Euros pr year. The capital costs pr. speed camera section compromise 5.500 euros pr year and the annual operating costs is about 25.750 Euros pr year.

This number is not adjusted for the inflation rate that has occurred after 1997 and based upon the installation of wet-film cameras which are less expensive than digital cameras. However, the operation costs associated with digital cameras are less than for wet-film cameras, so it is reasonable that the total annual costs of running a speed camera section with a digital camera is believed to be roughly the same.
Elvik (1997) estimated the benefits of 64 speed camera sections described in Krohn’s report in 1996. The estimated benefits were about 20.875.000€ per year. Of these, 15.500.000€ were reduced accident costs, 4.750.000€ reduced vehicle operation costs and 625.000€ reduced environmental costs.

The total cost of running the 64 cameras was estimated to be 2.375.000€.

Thus, it was concluded that speed cameras operative in Norway in 1997 provided a benefit that was substantially larger than the costs (F = 20.875/ 2.375 = 8.8).

**4.4.3.4 Public acceptance**

Surveys carried out in several countries show the acceptance of measures to enforce speed limits, speed cameras among them, to be high. Over 70% of the Norwegian population is favourable to the measure, percentage being almost 65% in the case of Spain and similar in other European countries. A recent poll in the Netherlands showed an increase of acceptance to about 76%, this was partly attributed to the new speed enforcement methodology on the motorways: average speed measurement.

It is important that authorities can always give a clear image of the purposes and intentions of the installation of enforcement systems, and so far, this similarly high acceptance in countries as different as Norway and Spain proves that people are indeed aware of the value of this kind of measures.

**4.4.4 Legal issues**

It happens in several European countries that it is the driver of the car who is the responsible part if a speeding violation occurs, not the owner of the vehicle. Because of this, in the countries where such legislation applies, it is very important that the photos have a high quality making it possible to both identify the driver and the registration number of the vehicle. It is the owner of the vehicle that is contacted if a speeding violation is registered. If the driver cannot be identified by means of the picture or if the owner cannot (or refuses to) identify who was driving the car, the charges are usually dropped.

And as it happens with other still or motion picture based enforcement systems, it is not allowed to keep identifiable pictures of passengers occupying the vehicle.

**4.5 Section control automated enforcement**

**4.5.1 General background**

In the mid 90s, a number of Member States started trials of a new speed enforcement system. This new system was not based, as were spot speed systems described in the previous point, in the measurement of the speed of a vehicle at a given spot and the instant decision as to whether the vehicle was driving above the speed limit at the spot to carry on the enforcement procedure. The new system was based in the apparently simple idea of checking the precise moment when
a car entered a given road section and the moment when it left it, and with the time it took the
car to make the (known) distance, calculate the average speed the car had been driving at. If
this average speed was above the limit, enforcement follow up was to be engaged.

Again, this apparently simple idea is not as straightforward to implement, due to a number of
different reasons, ranging from technology limitations which have not been overcome until
recently, to legal issues, which are in fact what are preventing the widespread use of this
enforcement systems.

The basic scheme of a section control system can be described as follows (figure 4). Cameras
are installed typically at gantries at the entry and the exit of a given road section typically
several kilometres long.

Cameras at both points are constantly taking pictures of the vehicles going in and out the
section, as many as legally required in the country, and most importantly, of the vehicle’s
licence plate, along with other information such as the precise time where the occurrence took
place (all together forming a register uniquely identified by means of what is called a
fingerprint, generated and managed also by cameras’ accompanying equipment), while a
processing unit checks also constantly for licence matches from both sources – entry and exit
cameras.

Whenever a match is found, that is, the system acknowledges a car with a given licence
number entered the section at such time and got out at such other time, the precise time
elapsed, and therefore the average speed along the section is calculated. As it was said before,
if this calculated average speed is above the limit, the image of the licence plate is sent to the
traffic authorities for identification purposes of the owner of the vehicle, after which the police
authorities make the corresponding notification and run the administrative or legal follow up
procedures.
4.5.2 Some implementation details

Here follows a brief technical description of the implementation of a section control. In this case, the Dutch implementation at the A-13 motorway between Rotterdam and The Hague is detailed, although the equipment involved in any similar installation is basically the same.

Billboards at the beginning of the section control area communicate to the road user that enforcement is effective continuously. Electronic matrixes indicate the maximum speed on all gantries, each 300m.

A complete digital image capture sub-system for up to 4 VIS cameras is mounted on the gantries at the beginning and the end of the section.

The system has interfaces to a wide variety of vehicle detectors and a serial interface to communicate with up to 4 lane controllers and the controllers of the matrix system. If a matrix showing 80 km/h is down or malfunctioning, this will be detected immediately; all matrixes are checked continuously separately by a specific algorithm.

System parameters are stored continuously in the fingerprint files and if a malfunction is detected, the system shuts down automatically.

This ensures 100% guarantee that the system worked properly when a violation is detected and captured and as such, it cannot be contested in a court of law.
GPS receivers are checking the time continuously and ensure the proper functioning of the system as well. If the GPS receivers are malfunctioning or are jammed, again, the system shuts down automatically, these parameters are recorded as well.

At each side on top of the gantry, a light detector is in place, adjusting the cameras for the varying light conditions. At night, a near infrared flash is used, hardly visible for the motorists.

Two roadside cabinets are situated along each carriageway. Here the images are stored temporarily for calculation and initial processing (fingerprinting). These cabinets have protection against tampering. If the cabinet is opened wrongly, the system shuts down immediately and the hard disk is erased immediately, leaving no data on the disk. The system is dead then and has to be rebooted manually after checking up.

### 4.5.3 Analysis of section control enforcement systems

Due to the relative novelty of section control systems, and even more, the fact that legal analysis of the system are preventing implementation of trial systems or the careful and detailed study of the results of the trial systems, information about section control systems is also scarce.

Here are presented the main results of the studies carried out in The Netherlands and Austria, with section control implementations in the A-13 motorway between Rotterdam and The Hague and the Kaisermühlen tunnel in Vienna respectively.

#### 4.5.3.1 Effects on speed

Looking at the results of both implementations studied, installation of the section control resulted in a clear reduction of average speed (KfV, 2004). In its first year of operation, a reduction in average speed by more than 10 km/h was recorded (figure 5).

Speed measurements showed the average speed of all vehicles to be 85 km/h, whereas this value decreased to about 70 km/h shortly after the introduction of the measure. Further speed measurements carried out after a 6 month period revealed that average speed on this road section has levelled off to 75 km/h, due to the fact that drivers tend to follow regulations in a very strict manner right after their implementation, but less some time afterwards due to unintended behavioural adaptations ("kangaroo effect").
Figure 5. Effect of Section Control on average vehicle speed. Kangaroo effect

Analysis regarding speed reduction depending on time of the day (table 2) reinforced the aforementioned result, and additionally provided a basis for the further analysis of vehicle emissions, more details of which will be described later in this chapter.

<table>
<thead>
<tr>
<th></th>
<th>Passenger cars</th>
<th>HGV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Daytime</td>
<td>85 km/h</td>
<td>75 km/h</td>
</tr>
<tr>
<td>Nighttimes</td>
<td>95 km/h</td>
<td>75 km/h</td>
</tr>
</tbody>
</table>

The analysis of data from the Dutch section control shows a similar reduction in average speed, and most notably in HGV too, for which a reduction from an average speed of over 90km/h to under 80km/h was recorded.

4.5.3.2 Effects on accidents

Accidents are statistically rare events. Part of the nature of such events is that the precise time and place of their occurrence, as well as the precise nature of their impacts, are hardly predictable, i.e. in some periods, the recorded number of accidents on given points of the road network are greater (or less) than the average values expected for those points. It can result that the recorded number of slightly injured road users in a given year is not necessarily representative of the mean annual number. Thus, analysis of road accidents and injuries, and establishing the effects of a certain measure on them requires some care.

A detailed study of the Austrian section control implementation, detailed in (KfV, 2004), in which a thorough analysis of data on accidents and accident severity, along with the development of a mathematical model to correctly assess the impact of the section control on the accidents shows an improvement.
Statistical inference which draws conclusions about a population based on sample data. It also provides a statement, expressed in the language of probability, of how much confidence we can place in the conclusions (table 3). The different values for the safety effect of the following table act as estimators of the (unknown) population parameter.

**Table 3. Safety effects of section control on accidents and accident injuries**

<table>
<thead>
<tr>
<th></th>
<th>Odds ratio</th>
<th>Safety effect [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury accidents</td>
<td>0.67</td>
<td>-33.3</td>
</tr>
<tr>
<td>Fatal and serious injuries</td>
<td>0.51</td>
<td>-48.8</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>0.68</td>
<td>-32.2</td>
</tr>
</tbody>
</table>

Figures in relation with the Dutch implementation are not available, but the results of the study reveal a similar positive impact of the section control, with a 50% reduction in accidents, and a “slight decrease” in road fatalities (ITS, 2004).

**4.5.3.3 Cost-benefit analysis of the system**

Again, it is important to note that the following figures are given based on Austrian section control systems, and therefore some care may be necessary when trying to extrapolate these results and analysis to other states. However, it is to expect that the main result, that is, that spot speed systems’ cost-benefit balance is positive, is equally valid in other countries.

Investment costs for the Section Control in the Kaisermühlen Tunnel add up to € 1,200,000 (2002 price). Construction work of gantries, cables and data lines to the Section Control server are included in this price. Annual costs of operation and maintenance are about € 60,000, covering a service contract of 4 service cycles per year plus additional repairs if the system starts malfunctioning. In order to not disrupt traffic flow, maintenance and repairs are done during night hours when traffic is usually very low.

According to the Austrian highway operator (ASFINAG), the Section Control system has a 10-year service life, beginning in 2003. After that period, software problems and missing spare parts for the hardware are expected to affect full operation of the system. Investment costs are incorporated in the form of an annual capital cost assuming a 4 percent interest rate in real terms. Total annual costs (table 4) for operating the Section Control add up to € 207,949 per year.
Table 4. Total annual costs of section control in the Kaisermühlen Tunnel

<table>
<thead>
<tr>
<th>Expense factors</th>
<th>Costs</th>
<th>Annual capital costs [n=10, 4% p.a.]</th>
<th>Total annual costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment costs</td>
<td>1,200,000</td>
<td>147,949</td>
<td>207,949</td>
</tr>
<tr>
<td>Annual maintenance costs</td>
<td>60,000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of several factors that contribute to the benefits of section control, such as violations’ revenues, reduced environmental costs, reduced accident and injuries costs, etc. can be found in (Keller, Hausberger, 1994), (EWS, 1997), (Elvik, 1999) and Ministry of Interior databases, adding up to aggregate benefits of over 1.100.000€ per year.

Thus, it was concluded that the section control at the Kaisermühlen tunnel provided a benefit that was substantially larger than the costs (F = 1.100.000/210.000 = 5.5).

4.5.4 Legal issues

As it has been stated several times when talking about the section control enforcement systems, legal issues have sometimes prevented the full implementation of these systems in several countries.

The first issue arising is the validation of the digital image as a legal evidence, a problem which has been aggravated by the fact that images are not stored in any way in the digital device, as it happened with earlier spot speed wet film based systems, but instantly transmitted to the relevant authority. This means that not only the source, that is the camera- has to meet legal standards concerning quality or content, for example, but the complete register building process taking place in the camera equipment – bundling the image(s) along with the necessary additional information – and the following transmission to the authorities have also to meet strict security requirements that simply were not considered in previous enforcement systems.

Equipment and procedures are carefully looked upon by legal authorities for approval, a process which in occasions can be long and which is taking place now in several European countries.

More subtle issues arise when considering the concept of section control itself.

First, pictures are taken of every vehicle going through the section, and given the section control idea, stored at least until the vehicle exits the section, a time which is not, as it can be said to happen with spot speed systems, negligible. During that time, information about an individual who still has not been proven to commit any infraction is stored by authorities, which could be seen as an invasion of privacy, with the addition of the increased probability that such information could still be tapped or intercepted by third parties –which should not happen if the system is correctly designed, which again brings up the care necessary in system and procedures design and approval.
Another issue with section control is the fact that an infraction is supposed to be committed at a given place and time. Spanish enforcement legislation, for example, requires an infraction notification to specify this data. The concept of section control, in which an average speed has been calculated over a stretch several km long, actually makes gathering this information an impossible task.

### 4.5.5 Future possibilities of section control

The advances in computing in the last years have had their consequences in digital video technologies too, opening a whole new range of possibilities and applications in many fields, and enforcement is no exception.

Once the physical video enforcement infrastructure is installed, implementing uses other than speed enforcement requires probably just a proper software application development. As it was said, the increasing computing power available makes possible thinking of practically unlimited monitoring in terms of types of traffic violations that can be detected. Pilots have already started for seat belt (see chapter 6) and tailgating infractions (see chapter 7), apart from systems already in use for red-light running infractions in the Czech Republic (Fencl, 2005). Section Control already planned future applications’ development include infractions such as the tracking and tracing of suspicious or stolen cars, vehicle weight infractions, road use related infractions, overtaking infractions, improper lighting use, detection of dangerous driving patterns…
5. **Drink driving**

The members of the European Union all use screening and evidence devices for the determination of the BAC. These devices are adapted or adaptable for the various BAC limits in the EU and have to be type approved for each Member State and calibrated before they can be used in operational traffic policing.

Technology developments are applicable to these devices as well, but are not to be considered to be ITS specific. As sufficient technical documentation is available (also documented in WP 4 of Pepper) these will not be elaborated on in this Pepper deliverable.

5.1 **Drugs, the Rosita project**

Next to alcohol, the increase of driving while intoxicated where it concerns drugs and medicine is progressing at an alarming rate. Some indicators have shown that the percentage of driving while under the influence of drugs or medicine almost has reached the same level as driving under the influence of alcohol.

Therefore, the enforcement of this specific type of driving while intoxicated has become a point of concern for the European Commission as well.

2 projects have been carried out to analyse this problem and to draft recommendations and an EU approach to tackle this, those were the Rosita projects; deliverable 3 of the 1st Rosita project (Möller, Steinmeyer, et al., 1999) is reflected in this Pepper deliverable.

5.1.1 **Applicable Legislation within the European Union**

All countries of the European Union (EU) have legal provisions on driving under the influence of drugs (DUID). Generally, participation in street traffic is only allowed if one is capable of driving a motor vehicle in a safe and proper way.

If driving ability is impaired by substance abuse, one can be sanctioned, but impairment has to be clearly proven in court. This legislative approach is difficult to enforce, because it is difficult to document the impairment objectively.

Some states try to circumvent the difficulty of proving impairment by using legislation solely based on the analytical detection of drugs in the blood. Germany introduced such a law in August 1998 and in March 1999 Belgium put similar legislation into force. The biggest part of the European Union is still waiting and carefully following the activities of those states in the forefront. Table 5 summarises the situation on drugs and driving in the countries included in the Rosita survey.

The enforcement of legislation of this type depends mainly on the ability of the police forces to obtain the appropriate specimens from the population participating in street traffic. At this point, the authority of the police forces to collect human specimens – either for roadside testing
or for confirmatory analysis – is of importance. This authority is regulated by further legislation that differs from country to country.

In some countries the police forces are allowed to control and test the driving population randomly. Suspicion of an offence is not necessary for testing. The majority of countries however treat any roadside testing procedure as an intrusion into personal rights which can only be done if an initial suspicion exists.

Table 5. Overview on the legal situation in the area of DUID and the use of roadside drug tests.

<table>
<thead>
<tr>
<th>Country</th>
<th>Does legislation covering DUID exist?</th>
<th>Impairment or analytical approach?</th>
<th>Roadside testing for DUID allowed at this point of time?</th>
<th>Initial suspicion needed to apply a roadside drug test?</th>
<th>Roadside drug test devices in routine use?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Belgium</td>
<td>yes</td>
<td>Analytical/Impairment</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Denmark</td>
<td>yes</td>
<td>Impairment</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Finland</td>
<td>yes</td>
<td>Impairment/Analytical</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>France</td>
<td>yes</td>
<td>Impairment</td>
<td>no</td>
<td>-</td>
<td>no</td>
</tr>
<tr>
<td>Germany</td>
<td>yes</td>
<td>Analytical/Impairment</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Greece</td>
<td>yes</td>
<td>Analytical/Impairment</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Iceland</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Italy</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>yes</td>
<td>Impairment/Analytical</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Netherlands</td>
<td>yes</td>
<td>Impairment/Analytical</td>
<td>yes</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Norway</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Poland</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Slovenia</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Spain</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Switzerland</td>
<td>yes</td>
<td>Impairment</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Unit. Kingdom</td>
<td>yes</td>
<td>Impairment</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

To improve the process of gaining an initial suspicion, some states have introduced a training program for their police forces which should enable them to identify intoxicated drivers in street traffic based on physical and psychomotor signs.

Roadside testing devices are so far only used in Germany (here sweat or urine are the target specimens) and in Belgium (urine testing) on a routine basis, but some other countries have used urine, saliva or sweat test devices on an experimental basis with voluntary participation of the drivers.
Interestingly, the application of roadside drug test devices is prohibited by regulations in only very few European countries. In most countries drug test devices are not in use because of their low level of validation or their unavailability.

5.1.2 Operational Needs and Requirements of the Police Forces

Based on the national experiences and circumstances, European police forces have a rather clear picture what they need under their specific operational conditions. However, these needs and requirements differ from country to country and sometimes even from state to state within one country. Nevertheless, average tendencies for the requirements on roadside drug test devices have been established from the results of the survey.

Concerning drugs that have to be detected, the following classes of drugs are considered to be very important (in decreasing order of frequency): cannabis, benzodiazepines, amphetamines, cocaine, and opiates.

The preferred test configuration is a single use, multi parameter test, which is able to provide a clear, unambiguous test result on the above mentioned groups of drugs within 5 minutes. According to the respondents, saliva is the preferred test specimen for roadside testing due to its easy availability, the low invasiveness of sampling, and the good correlation with impairment. Sweat, on average, is the second preference because it allows testing without the collaboration of a driver, in combination with low invasiveness and good availability at the roadside.

5.1.3 Conclusion and Outlook

For the future it is necessary to further validate existing devices which are applicable to the detection of the abuse of drugs in street traffic. This includes urine tests but also saliva and sweat test devices. More effort has to be made on the investigation of the correlation between impairment and pharmacokinetics of illegal drugs in easily accessible body fluids (sweat, saliva). This will help to develop more reliable devices for roadside testing.

It is essential for most countries, to train police forces in the detection of drivers under the influence of illegal drugs. In most countries of the European Union further legal measures (e.g. taking a blood or urine sample but also the application of a roadside device) depend on an initial suspicion of DUID.

The development of optimal roadside test devices for the examination of saliva or sweat is a technological challenge.

Whereas alcohol is present in the parts-per-thousand level in the blood as well as in the breath of intoxicated drivers, drugs are usually present in the parts-per-billion levels in body fluids. Most relevant medical and illegal drugs do not appear in detectable concentrations in the breath of drugged drivers.
5.2 Immortal (Impaired Motorists, Methods of Roadside Testing and Assessment for Licensing)

The Immortal project (Competative and Sustainable Growth program Grow 2000) was a research programme concerning the accident risk associated with different forms of driver impairment and the identification of 'tolerance levels' applied to licensing assessment and roadside impairment testing (including drug screening).

IMMORTAL focussed on two societal needs that both contribute to quality of life, namely mobility and safety and provided added community value in terms of the generalisation of conclusions relevant to EU policy and standardisation of driver testing and assessment methods with respect to EEC directives.

The research focussed on chronic impairment from ageing, mental illness and disease, as well acute impairment from drugs, alcohol and medicines. The policy function addressed these and other impairment factors (i.e., fatigue, visual & perceptual deficiencies) and considered relevant countermeasures, including licensing and impairment testing.

The technical and scientific objectives of IMMORTAL are to:

- Investigate the influence of chronic and acute impairment factors on driving performance and accident risk;
- Recommend criteria ('tolerance levels') for high risk categories of impairment;
- Provide key information to support formulation of European policy on licensing assessment and roadside testing.

5.3 DRUID (Driving Under the Influence of Drugs)

In November 2006 the DRUID project started. Druid stands for Driving Under the Influence of Drugs. Led by BAST, the German Federal roads Authority, this EU co-sponsored project test about 10 devices for oral fluid screening on their practical and scientific perspective.

Tests will be carried out by police enforcement teams in a real world environment on a voluntary base.

The project will run for 4 years, 17 member states with 35 partners participate in this project. Partners are represented by police, Ministries of Traffic, universities and research centres.

First results from a thorough evaluation are expected within 3 years.
6. Seat belts

At the moment there is not a specific ITS technology or technology development for the automated detection of seat belt compliance used in any Member State, but we will present here some ideas of a pilot being conducted in Finland.

6.1 VTT automated seat belt enforcement pilot

There is a research carried out by the VTT in Finland, in which automatic seat belt enforcement using digital cameras is being tested. Here follow some details of the project.

6.1.1 The purpose of the VTT pilot

The aim of this automatic seat belt detection pilot was to find out if the seat belt detection could be automated using innovative technologies and what would be the optimal camera and shooting parameters, estimated detection success, and cost of the real system.

The work was divided into 3 different phases as follows:

Phase 1:
Estimate what are the optimal camera parameters (angle, distance etc.) and cost of the real system

Phase 2:
Estimate the percentage of violations that could automatically be detected from speed camera images.

- capture image material using different camera angles and distances
- perform semi-manual analysis for estimated detection success

Phase 3:
Estimate the improvement when using automated seat belt enforcement and do cost-benefit estimates for different speed limit areas (this is planned to be carried out in task 3.2).

6.1.2 Camera and shooting parameters

The first thing to do was to estimate the optimal camera parameters. After measuring the angles of about 30 different windscreens and the corresponding maximum camera angles it was found that the maximum camera angle should not be more than 15 degrees from the ground level in order to see the seat belts in different types of vehicles. In the test situation the camera could not be lifted up higher than 5 meters. The height of 5 meters and the angle of 15 degrees meant about 12 metres distance from the camera to the car’s buffer as shown in figure 6. In theory, it
seems to be possible to survey from the same picture also the truck drivers’ seat belt use but trucks were not photographed in this pilot.

In addition, imaging two adjacent lanes at the same time was found out to be possible if camera can be placed between or nearly between the two lanes.

![Camera Parameters](image)

*Figure 6. The camera parameters used in the pilot and the optimal camera angle*

In the pilot the reflections of sunlight were eliminated, as cars were driven under a shelter. It is presumable that reflection problems in real life can be handled by placing and pointing the cameras properly, and/or by the use of a high power IR flash. Without such shading or flash the reflections in sunlight make it impossible to detect the seat belt use.

After having the proper imaging circumstances 11 drivers with different types of vehicles were photographed. In addition, one driver was photographed in 4 additional circumstances (using totally black clothing, zooming and having extra light from the side and at a facial angle). Images were taken with an Olympus C770 Ultra Zoom camera. The resolution was ~0.2 cm/pixel (when using zoom: ~0.15 cm/pixel) and the picture area was ~6 metres (using zoom: ~4 metres).

### 6.1.3 Image processing

*Finding the location of the seat belt*

Even though the seat belts in a car are relatively small objects within the field of view of the camera, the car structure can hierarchically be segmented to typical areas of interest, so that the correct location of the seat belts can be estimated fairly reliably. This is illustrated in *Figure 7.*
Image analysis

Due to the strict resource limitations of this pilot, only the critical parts of the image processing tasks were evaluated. The segmentation process shown in the diagram for most parts is already routinely performed in such enforcements tasks as e.g. license plate recognition, and thereby does not require additional consideration. Instead, we concentrated on the final, critical segmentation task, namely extraction of the seat belt from the background of the driver clothing.

In this pilot the image processing was done with UTHSCSA Image Tool -program (freeware software). First the images were converted from colour to gray scale images. Then the histogram analysis was performed for the regions of interest (seat belt area and areas near the seat belt (see figure 8) and also the mean gray value and its standard deviation was calculated.
Figure 8. Selected areas from which the histograms were taken

Results of the image analysis

It is obvious that if the contrast between the seat belt and the background is clear by human eye inspection, it can be segmented in machine vision, too. However, sometimes also such imagery that is difficult for routine human checking, can be inspected by machine vision. Figure 10 is an example of a case where the visual contrast is quite low, and the gray levels concentrated to the very dark values. Even for such cases we have some possibilities.

As seen in the following histograms (figure 9), the mean gray value and its standard deviation of seat belt and background differ recognizably. If the difference is less than about 15 (for a typical 8 bit scale between 0 and 255) it is difficult to see the seat belt and as well detect the seat belt use automatically.
Figure 9. Histograms from areas presented in the previous picture (areas left to right)
Of the 11 vehicles tested, in 10 cases the differences of mean gray values between seat belt and background were more than 15 and seat belts were easily seen from images.

As an exception when seat belt was beige and driver’s clothing nearly the same, the seat belt was quite well visible, but the difference was below 10. When the driver used white clothing and the lining of car was black the difference was about 160.

Another problematic case was the combination of a black seat belt, clothing, and car’s lining. In this case differences of mean histogram values were very tiny and even zooming did not help the situation. However, in cases like this, some extra light from an alternative source could improve visibility.

Seat belt detection principle: automatic or semiautomatic processing

The histogram analysis described in the previous section can be used for automatic or semiautomatic seat belt detection. The hierarchical segmentation described in Figure 7 will provide limited candidate areas for approximate seat belt location. Within such an area, histograms are calculated for several regions of interest whose area correspond to the area covered by the seat belt (however, truncated in the length direction), as illustrated in figure 8. If sufficient difference is found for neighbouring areas that are separated by the belt width, we have good evidence that the person is wearing a seat belt. Such clear cases can automatically be excluded from any manual processing, thereby saving manual work. As seen in the statistics, this part of the cases makes a clear majority.

For unclear or negative results, further semiautomatic processing can be performed. Also, for such cases image processing can assist the human operator. For example in cases where the histogram analysis provides an unclear resolution where the average gray level difference is less than 15, the image can be thresholded to binary image by setting the threshold value in between the two histogram peak values (see figure 10 and figure 11).

Alternatively, less dramatic gray level expansion can be performed around this value for easier visual inspection.

At unclear cases manual post-decision has to be made.
Figure 10. Original picture in which the seat belt is not visible

Figure 11. Binary image using thresholding. Now the seat belt is visible

Results of the image processing are gathered in *table 6*. 
Table 6. Results of the VTT seat belt enforcement pilot image processing
(\(\approx\) it is not exactly sure whether the seat belt is visible to the eye or not).

<table>
<thead>
<tr>
<th>Image nro.</th>
<th>Is seat belt visible? Yes/No</th>
<th>What is the difference of mean gray value between seat belt and background? Under wheel/above wheel</th>
<th>Remarks</th>
<th>Is seat belt visible on binary image? Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Yes</td>
<td>19/19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>?</td>
<td>12/6</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>3.</td>
<td>Yes</td>
<td>24/16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Yes</td>
<td>31/30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Yes</td>
<td>42/43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Yes</td>
<td>9/7</td>
<td>beige seat belt and clothing, seat belt was not shown under the wheel</td>
<td>Yes</td>
</tr>
<tr>
<td>7.</td>
<td>Yes</td>
<td>38/22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Yes</td>
<td>113/119</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Yes</td>
<td>61/46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Yes</td>
<td>34/34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Yes</td>
<td>157/166</td>
<td>white clothing</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>No</td>
<td>7/2</td>
<td>black clothing</td>
<td>Yes</td>
</tr>
<tr>
<td>13.</td>
<td>No</td>
<td>10/1</td>
<td>used zooming</td>
<td>Yes</td>
</tr>
<tr>
<td>14.</td>
<td>No</td>
<td>4/4</td>
<td>extra light from facial angle</td>
<td>?</td>
</tr>
<tr>
<td>15.</td>
<td>Yes</td>
<td>15/34</td>
<td>extra light from side</td>
<td></td>
</tr>
</tbody>
</table>

At this pilot the success of automatic detection was about 83 % because there were 2 unclear situations where manual post-decision was needed. However all the images were taken under optimal circumstances and with 0 km/h speed. In addition, the segmentation was here done manually, and obviously, in real situation, there are also segmentation failures, as well as overly dirty or darkened windshields, drivers that have just turned to some unexpected positions, and some other error sources. However, the main advantage comes clearly from the fact that only the small fraction of unclear situations need to be manually checked. It is clear that for collecting more reliable statistics, a complete functional system and associated software needs to be built, which is beyond the scope of this study.

6.1.4 Planning of a real system

Estimation of cost

The real seat belt detection system requires the following components (rough cost estimation is in brackets):

- w rack and covering (~2000 €)
- w high resolution camera and flashlight (~20000 €) [1]
- w computer handling the data (~15000 €) [1]
- w server (operates the image processing program and sends messages to the office system) (~10000 €)
image processing program (free, excl. development costs)
GPRS/3G data transmission (~6 €/MB, ~7 kB/image)
office system (pc) (~2000 €)

The server and image processing program are recommended to be near to the camera because otherwise all the images need to be transferred to the office system (in this case only those images that lead to a penalty or are unclear need to be sent). A conservative estimate for the costs of the real system is something like 50000 € not including data transmission neither any personnel costs in programming, testing, installation, maintenance or office work (sending of fines, manual checking). Supposing that about 8% of passenger’s cars drivers don’t use seat belt (average value on highways in Finland at 1996–2002, include reference!!) and about 10% of all cases are unclear (system out of order, vandalism, seat belt usage hard to recognise etc.) means sending roughly 4300 images a day when traffic flow is 24000 vehicles/day. 4300 images per day is about 30MB, which pays ~180 €/day and ~5400 €/month. Data transmission costs are likely smaller than 6 €/MB when transmission mounts are huge.

**Estimation of detection success**

It is hard to estimate the detection success of a real system. Comparing to traditional police enforcement automatic enforcement system operates 24h/day tirelessly and without any gap, except only out of order situations. According to this pilot it seems that the detection success of automatic system can be very close to the situation of visual detection.

It is obvious that no matter how reliable the system is always some part of the images need to be processed manually. However the manual processing is easier and quicker when, in addition to the original image, also a contrast enhanced image exists.

**6.1.5 Conclusions**

When the seat belt use is visible to the eye it is very likely that it can also be detected automatically. It proved that when the seat belt is visible the mean gray values of it and background differ more than about 15 units in a scale of 0 to 255 in a gamma corrected gray level map. If the difference is less than 15, manual image analysis should be done. Also manual handling can be assisted by clever image enhancement, e.g. by histogram manipulation and/or thresholding. The event processing graph is illustrated in *figure 12*. For achieving good average visibility to the seat belt area with different windshield constructions, rather shallow angle for the camera, about 15 degrees with respect to the ground level should be used. An extra light from the side of the car was found out to improve the visibility in such cases where there was dark background for the dark seat belt.
**Figure 12. The process of automatic seat belt detection**

This will be tested in a pilot scheme; if feasible for operation, next step will be to have it type approved in order to allow these images as full proof before the courts.
7. Other infractions

Other infractions are considered here as the results on technology and infrastructures implemented in detecting these other infractions could prove useful when focusing on the three main infractions pointed out in the EC recommendations.

7.1 Tailgating: former experiences in the Netherlands

A digital imaging technology based system was first tested and introduced in some problematic motorway stretches in 1999.

The basic technology behind the system was the VCS 3.0 Video Control System developed by the German Vidit company.

Approved and certified by both German and Dutch authorities for enforcement use, the system makes it possible to analyse precisely timed live video recordings of suspected tailgating, using clearly defined road sector measurements. Distance between individual vehicles can then be calculated, and, when considered an infraction, processed into evidence acceptable in court. In any case, the process takes around 10s, so immediate notification further down the road is possible.

Results show that VCS is already effective in discouraging certain drivers from tailgating.

7.2 The CLAUDIA project

The VCS system is undergoing further development to make it possible for it to be applicable to other types of infractions which could be detected using the same concept.

The CLAUDIA (Catching Legible vehicle data to Acquire Unlawful behaviour by Digital Information Assessment) goes in that direction, with the aim to be used for the surveillance of infractions such as:

- Enhanced Tailgating (*figure 13*).
- Improper vehicle lighting.
- Wrong lane driving.
- Licence plate related infractions.
- Overtaking infractions.
- Safety belt compliance infractions.
- Special transports monitoring.
Figure 13. VCS 3.0 sample screen
PART II: WARNING/MONITORING AND CONTROL/SURVEILLANCE TECHNOLOGIES
Introduction

Passive enforcement can be regarded as the technology that is being developed and brought to the market by the industry with the aim to enhance road safety. This can be either integrated to the infrastructure or form part of the vehicle.

This technology does not address enforcement in the first place but has the potential to inform and/or support the motorist to drive safely and in compliance with the traffic regulations. It has not punitive impacts and is voluntarily in nature.

This supporting role can take many different shapes, as was said before, either being integrated in the infrastructure or in the vehicle, or taking a different approach to its study, being oriented to actively support the driver or just to make roads safer.

In this part of the document several of these supporting technologies will be described and analyzed, if only to get an idea of the variety of devices available to accomplish this passive enforcement support function.

Again, three major domains, following the EC Recommendations, will be mainly studied:

- Speed
- Drink driving
- Seat belt use
8. Speed

ADAS (Advanced Driver Assistance Systems), are being developed to assist drivers in their driving task. When designed with a safe Human-Machine Interface it should increase car safety and more generally road safety. About 90% of all traffic accidents can be attributed to human failure, which provides an indication of the increase in traffic safety that can be achieved by ADAS. Drivers require assistance during accident-prone manoeuvres, such as overtaking.

Specifically designed for the functionality of longitudinal control of the driver two specific tools have been designed, those are ACC (Adaptative Cruise Control) and ISA (Intelligent Speed Adaptation) systems. They can be combined and somehow control driving performance (giving some more initiative to the driver) and thus be considered as a complementary tool to support other more punitive measures (like enforcement, intended to avoid the risky driving behaviours). ISA limits the speed of a driver at the speed limit, which means that all drivers with a desired speed above the speed limit, will be limited at it.

8.1 ADAS for longitudinal control: Adaptative Cruise Control (ACC) and ISA

Adaptive cruise control (ACC) enhances classical cruise control and adds to the function to keep a certain driving speed, to automatically maintain a following distance to the preceding vehicle.

The distance to the preceding vehicle is measured by radar either with laser radar or millimetre wave radar. When the vehicle ahead is driving more slowly than the adjusted speed the ACC system will control the vehicle speed and follow the lead vehicle at a safe distance. Once the road ahead is clear again, the ACC will accelerate the vehicle back to the previous set cruising speed.

ACC, including Stop&Go, is generally regarded as a comfort function that helps and assists a driver to fulfil his/her longitudinal driving task. ACC is not designed to prevent or even eliminate collisions, but to provide additional comfort, whilst maintaining at least the same safety level. The benefits depend significantly on the headway being adjusted (different headway for optimal capacity impacts and traffic safety impacts). Nevertheless, according to the studies performed by many experts, ACC seems unlikely to have significant impacts on traffic efficiency in the near future. There is always the issue of technology penetration rates, they should increase above 20% in order to gain some efficiency impacts.

ACC is designed and sold as a comfort system and not as a safety system, but some studies have shown that there is the risk of drivers expecting ACC to work like a collision avoidance system and therefore reacting too late to stationary objects on the road, for example. Furthermore, the comfortable driving with ACC may reduce driver vigilance. Most of the implementation strategies for ACC that are described in the following aim at minimising the risks connected with its implementation as it is at the moment. Another objective of the implementation strategies is the technical and technological development of ACC to enable the
integration with other ADAS *(Advanced Driver Assistance Systems)* and this is the case of ISA which is going to be described bellow.

Besides, there are some initiatives toward the use of ISA combined with ACC systems.

For the case above presented of overtaking manoeuvre, ISA will decrease the possibility of meeting slower vehicles and therefore the frustrations of not being able to overtake will be less. Cruise control, on the other hand, could have the opposite effect of ISA.

With cruise control, a driver can choose the cruise speed and could therefore choose a speed above the speed limit, welcome. ADAS could assist drivers with their overtaking task and therefore have potential towards excluding overtaking as accident causation. Having in mind this example it is easier to understand that combined in a support/control application they might have some influence in road safety and thus alleviate the necessity of enforcement measures for speed.

### 8.2 ISA: Intelligent Speed Adaptation

Intelligent Speed Adaptation (ISA) is a concept that has been evolving along the years since it was first conceived some 15 years ago. And while the precise definition of what is ISA is still not clear, the concept is *(PROSPER, 2005)*.

ISA is a group of functionalities with the aim of providing the driver with assistance to comply with the required speed limits. It is still the mechanism by which this may be achieved what is not consistently understood or implemented, as neither is the detailed functionality that may be presented to the driver.

This lack of clear ISA specifications has caused that there are as many different ISA systems developed as different institutions working on the subject. Nevertheless, it is possible to make a basic classification according to the level of assistance the system provides to the driver.

Thus, ISA can be said to be:

- **Warning or Informative** when the ISA vehicle device just gives the driver information of whether the speed limit has been surpassed, and additionally of what was the speed limit applicable

- **Active** when the ISA vehicle device incorporates means of physically interfering with the car’s engine or accelerator to effectively prevent the car driving above the limits, or at least to make it difficult

One common aspect of all major ISA trials in the EU is the fact that user acceptance is quite high. Even more remarkably is the fact that the rate of acceptance was higher after the pilot than before. In general, drivers felt comfortable with the system and appreciated the traffic easing effect.

ISA, without uttering any preference for the passive or active type here, has to be considered as a system with a very high potential for preventing drivers from speeding and achieving compliance with speed limits in a major way.
Again, many studies have been carried out in relation with ISA systems, the main results of a large scale Swedish trial on ISA (ISA, 2002) are annexed to this deliverable (Annex 3).

8.3 SpeedAlert

8.3.1 Background

Activities related to Intelligent Speed Adaptation (ISA) started in the mid of 90’s with initiatives from Sweden, UK and the Netherlands. Since 2000 several other EC Member States have launched national trials such as Finland, Norway, Denmark, Belgium, France, and Austria. These national activities came to highly valuable conclusions about potential benefits of such in-vehicle speed management system to road safety and with very encouraging results regarding user acceptance and transport policy.

Following on these first results, ERTICO, with its partners, identified the need for cooperation between public and industry sectors to address European level issues. Therefore it was decided in 2001 to set up the SpeedAlert Committee aiming at establishing a discussion platform with key stakeholders from public authorities and industry and developing a sustainable consensus on in-vehicle speed information and warning system.

As a first output of these discussions, a strategy Paper produced in 2002 jointly by Public Authorities and Industry presented the common key principles:

- In-vehicle speed information and warning can contribute to improve safety and mobility (in accordance with EC White Paper on European Transport Policy for 2010)
- The driver shall remain in control of the vehicle at all times, and is responsible for driving at a safe speed for the prevailing conditions
- Fitting and use of any system of in-vehicle speed information should be voluntary
- Evolution towards appropriate variable speed limit information relevant to dynamic conditions (traffic, weather, road…)

The second step was the SpeedAlert project (May 2004-April 2005) co-funded by EC DG TREN with a consortium composed of public authorities and industry partners and reinforced by a Consultation Group. SpeedAlert project ran in close cooperation with the PROSPER project also co-funded by EC DG TREN and the two projects had complementary roles and objectives.

8.3.2 SpeedAlert objectives and results

The SpeedAlert project’s main objectives were to harmonise the in-vehicle speed alert concept definition and to propose the first priority issues to be addressed at the European level, such as the collection, maintenance and certification of speed limit information, to enable a broad take-up of speed alert systems throughout Europe.
Speed Alert’s main results include:

- A functional architecture and associated technical building blocks (figure 14).
- Roadmap for deployment taking into account user needs, technical feasibility and available solutions.
- List of recommendations to support successful implementation of speed alert systems.
- Consolidation of broad consensus through the Consultation Group and its dedicated workshops and intensive cooperation with relevant EC projects (PReVENT IP / MAPS&ADAS, GST IP / Safety Channel, EuroRoadS, PROSPER).

![SpeedAlert architecture](figure 14)

8.3.3 The speed limit categories agreed in SpeedAlert

Speed limits are the most common traffic regulatory mechanism for road traffic.

Though every motorist understands the concept of “speed limit”, the varieties of speed limits relevant to speed alert systems are still extensive, and must therefore be categorised and defined in order to get an overview of the situation and to allow comparison between countries.

In the SpeedAlert deliverable 2.1 “Common definition of speed limits and classification” common denominators have been developed for a harmonised classification of speed limits that can be used as a basis for the SpeedAlert Requirements and defining the data coding process.

As part of this work speed limits have been divided into general (implicit), and specific (explicit) speed limits.
The general speed limits are defined in national speed legislation as the basic framework for road traffic speed limits. These speed limits are systematically not signposted along roadside. As these speed limits are nationally defined, they are however presented at border crossings to inform foreign drivers entering the country.

The specific speed limits are deviations from general speed limit rules and are always required to be explicitly signposted along the roadside.

An overview of the defined categories of general and specific speed limits can be found in the Annexes of this document (Annex 4).

8.3.4 The availability of actual speed limit data

An important factor when introducing SpeedAlert systems will be the access to speed limit data. The road-user experience of quality in the system will mainly be based on the feeling as whether the SpeedAlert system in the car comprise the same information of the present speed limits as the user can read from the road signs outside the car window. A first step in the introduction of SpeedAlert on a broad area was to focus on speed limits that are not varying and speed limits that vary versus time in a predefined way.

A simplified method to collect speed limit data, basically taking into account the quality expectations of the motorist described above is to just collect the position of signs and put the data into a digital map.

Such work is today provided by map makers on their own initiative but on a limited road network, mainly intended to be used in route guidance and fleet management systems to estimate travel time. In some cases data collection is also provided by road authorities.

Later on, a harmonisation between the EU Member States in the management of speed limit systems would put focus to and improve the observance of the speed limits which together with enhanced enforcement would lead to improved traffic safety.

To be able to reach the goals of the SpeedAlert project it will be important that national bodies within the European Union as well as the EU commission promote a harmonised, efficient supply of speed limit data from all Member States.

A core issue in the data provision chain will be the exchange of data between public authorities and map providers in the future. Defining a harmonised exchange format for this step will be a difficult task.

Even if on both sides export of data is possible in currently existing exchange formats like RADEF or GDF, this does not guarantee an easy transfer of data.
8.3.5 List of SpeedAlert Recommendations

The SpeedAlert Consortium defined and agreed on a list of recommendations to support successful deployment of speed alert applications. The deployment was presented as a three-phase approach:

- **Phase 1:** Autonomous system for static speed limits, short term (2006). Has already started thanks to initiatives from public and private sectors. Public Authorities can decide to take the leadership like in Sweden by deciding to equip their vehicle fleet with a speed alert system. Industry is also playing a major role. In addition to manual speed limiters already available in an increasing number of new cars, first generation of speed alert applications starts to be marketed as an extra feature of navigation systems, based on the initial data collection of static speed limit organised by map makers covering motorways and main roads in Europe. There will be a limited coverage of the road network which is defined by public authorities, according to national road safety issues; starting with motorways and main roads.

- **Phase 2:** Enhanced autonomous system for static speed limits, medium term (2009), full coverage of road network and incremental map update.

- **Phase 3:** Cooperative system for variable speed limits, long term, (2015).

The full list of recommendations can be found in detail at the Annex of this document (Annex 4).

8.4 Speed feedback signs

These are signs showing the speed of an individual road user usually by sensors dug beneath the road surface registering the speed of the vehicle or the use of a standard Doppler radar. This equipment is connected to a board. The board gives feedback to the driver with the text “Your speed is xx km/h” or “You drive above the speed limit” or “You drive above 70 km/h” (in the latter case the speed limit is e.g. 60 km/h). More sophisticated versions of the equipment can read and display the number plate of the vehicle being monitored and to which the message is directed. The driver is thus given feed-back of his/her speed and a violation of the speed limit is thus –in an initial approach to these systems- not sanctioned in any other way.

8.4.1 Effects on speed

An evaluation study of individual feedback signs in Norway carried out by Vaa, Christensen and Ragnøy in 1994 concluded that the average speed was reduced by 1,2-6,8 km/h after the signs were put up as compared to before. The drivers reduced their speed over some distance – i.e. there was some "generalization in space".

There is no clear evidence of "generalization in time". The speed reductions seemed to disappear when the feedback sign was removed. There was, however, some tendency of a time generalization of 1–3 days duration.
8.4.2 Effects on accidents

There is to our knowledge only one study (from the UK) estimating the effects of individual feed-back signs on accidents. The study was based upon a small number of accidents, and the results showed a (non-significant) decrease in injury accidents of 41% on sections where individual feedback signs for speed had been erected.

8.4.3 Costs of the measure

The total investment cost for an individual feedback sign for speed is about 20 000 Euro, and the annual running cost is about 5 000 Euro. Due to the uncertain effects of individual feedback signs for speed upon accidents, cost-benefit analysis has not been carried out.

8.4.4 Potential problems of the measure

Vandalism

Everyday experience demonstrates that passive traffic survey equipment is often the object of vandalism, so it is not unlikely that enforcement equipment in general, and more particularly easily accessible, such as these feedback signs may prove a focus of resentment.

Potential misuse of the equipment

There is a considerable potential for misuse of the permanent installations of speed feedback systems. Firstly, research conducted in Australia has shown that there has been sufficient anecdotal evidence to suggest that where permanent systems are used, an upper limit of the speed displayed should be set, or alternative warning messages used. Systems without upper boundaries tend to lend themselves to drivers attempting to set high speed records. Reckless drivers are soon aware of the lack of enforcement following operation of the device, and use it instead just to check how fast they can drive through the section.

There is also the opportunity for the familiarity of speed feedback systems to have an impact on the level of respect a motorist will afford the system. Without a Police presence in the area, motorists will soon learn to disregard the warning they may be receiving from the devices. Any instant change in motorist behaviour through the systems tends to be lost after repeatedly driving through without any form of prosecution.

8.5 Variable speed limits

The EU traffic goals imply a non-acceptance of any road fatalities or injuries, with the aim of reaching a society where traffic does not claim lives. And they demand a complete review of all the factors that affect road safety – particularly speed.

\[1\] Mabbott, Cairney, 2002
Many serious accidents could be avoided if drivers better adjusted their driving speeds to the traffic situation. Most people are aware of this, but far from everyone acts accordingly. Many tend to drive at the highest permitted speed, even if rain, rush-hour traffic or poor visibility means that the speed should be lower. It is also quite common that drivers exceed the speed limits when traffic conditions are more favourable.

Traffic authorities in Sweden believe that more drivers will comply with speed limits if these are variable – if they change when the traffic situation does (SRA, 2006).

### 8.5.1 Variable speed limits in practice

Weather conditions and rush hour traffic are not the only factors to consider. Some other different traffic situations where variable speed limits could change driver attitudes and their behaviour in traffic, thereby improving road safety and accessibility include:

- Road locations with heavy traffic and queue build-ups
- Bus stops proximities
- Slip roads, intersections and left turn (right turn in the UK) situations
- Bad weather and road conditions
- School proximities.

Different types of equipment would be installed in the aforementioned locations depending on the purpose. Sensors in the roadway register when vehicles drive by, including how many. Movement detectors register lighter vehicles, such as bicycles and mopeds. Weather stations monitor temperature, precipitation, and road conditions. At some locations the road is monitored by video cameras.

The information received from this equipment is usually analysed automatically and the speed display setting is changed according to pre-set limit values. The information is also sent to the traffic information centres, where, in certain cases, the staff on duty decides which speed limit to display.

![Figure 15. Crossroad variable speed limit practical example](image-url)
8.5.2 Field trials in Sweden

Since 2003, Swedish Road Administration has conducted a number of variable speed limit trials at different sites, where adjustable road signs have been installed to display either a variable statutory or a recommended maximum speed limit, depending on the traffic conditions or circumstances at hand (figure 15).

The speed can vary between 30km/h and 120 km/h in 10 km/h steps depending on the test site.

8.5.3 Field trials findings

The preliminary evaluation of the system application showed that the average speed decreased by 5–15 km/h when variable speeds are used to lower the speed limit at intersections, and by 3–6 km/h when the speed limit remained unchanged from the former situation. Even those who drove fastest (85 percentile) reduced their speed.

The majority of road users are in favour of variable speed limits. The most positive effect was experienced by those turning from the secondary side road onto the primary road, a manoeuvre that was also considered most problematic prior to the introduction of variable speed limits. It also seems that drivers have become better at keeping within the speed limit and that variable speeds have a good effect on rule compliance.

The technology and organisation have worked far beyond expectation. The reliability target was set extremely high – 99.5%, which means a maximum of 45 shutdown hours a year. All in all, the figure reached for the intersections studied was 99.8%. Despite this, it is still difficult to achieve socio-economic benefits.

Conclusions concerning intersections

The following conclusions can be drawn about variable speeds at intersections on rural roads. The method can be an option:

- on primary roads with a relatively high traffic volume (> 10 000 AADT) where there is a moderate amount of traffic on the side roads (20–30% of the volume on the primary road)

- on other primary roads with restricted visibility.

In cases other than the foregoing, it was found that other solutions could be more suitable:

- where there is a relatively low percentage of traffic on the side road (< ca 10%) dynamic warning signs are preferable (a VMS indicating "crossing traffic"). The same criteria apply for activating these signs as for variable speed signs.

- where there is a relatively high percentage of traffic on the side road (> ca 40%) the use of a fixed, local speed limit (a traditional metal sign) should be considered.
If there are several situations that activate a warning or speed sign, a supplementary sign/special information panel should be used to explain the reason for the speed reduction/warning.

There is a limited number of intersections (perhaps about a hundred) within the rural road network where the traffic volume is 10,000 AADT. There might be more of these on municipal roads, but no inventory has been made. Simpler and more cost effective solutions are being studied for intersections where there is a somewhat lower traffic volume.
9. Drink driving

9.1 Alcolock

ETSC\(^2\) experts estimate that across the EU about 2% of all journeys are associated with an illegal blood alcohol level (ETSC, 2003). Moreover, many European drivers readily admit to driving even if they feel they could be over the limit (SARTRE 3, 2004). Drivers with an illegal BAC level cause about 30-40\% of all driver fatalities and 25\% of all driver injuries in Europe (ETSC, 2003). In the three SUN countries (Sweden, UK and the Netherlands), about 10-14\% of all fatal accidents are caused by a driver over the limit.

Alcohol interlocks could form part of a solution to reduce the problem of drink driving.

An alcolock, or more formally in Euro-bureaucrat-speak a “breath alcohol ignition interlock device” (BAIID), is fitted to a car’s ignition to stop a driver from starting it if he’s over the drink-driving limit. It prevents the starting the vehicles if the breath alcohol concentration exceeds a predetermined threshold of fail level. The alcohol inter-lock can also be set at different levels depending on the particular alcohol limit suited to the different drivers.

Some elements are also being developed to ensure that the system cannot be circumvented; for example re-testing after the car has been travelling for a certain distance. There is also another system, which allows the driver to start the vehicle as normal. The system analyses the driver’s breath during the driving. If trace of alcohol is detected the driver has to blow into a breathalyzer inside the vehicle. If the alcohol concentration is over the legal limit the driver has a few minutes to park the vehicle before the engine stops.

Alcohol inter-locks are currently used in driver rehabilitation programmes as well as some commercial transport companies in Sweden and the U.K.

The device is seen as a way to stop people who have been convicted of driving under the influence from offending again. Trials have been taking place in recent years in the US, Australia, Canada, and Sweden, though not always under this name. Experiences in the US and Canada have shown that alcohol inter-locks can lead to 40-95\% reductions in the rate of drink driving repeat offences. Field trials have shown that there is a 28- 65\% lower conviction rate if there is an inter-lock installed in the vehicle, where the 65\% lower rate is reached during the first year after installation. After some years the impact that an alcohol inter-lock can have as part of reducing drink driving repeat offences is estimated to be lower.

Alcohol inter-locks have been used in Sweden to rehabilitate voluntary drivers that had broken the law by driving with a blood alcohol content over the threshold level (0.2\%). The participants in the study had a high risk of recidivism and ran a four times higher risk of being involved in an accident than the average driver. After two years of use there was still no recidivism by the participants of the test group.

\(^2\) ETSC. In-car enforcement technologies today.
9.1.1 User acceptability

The acceptability of alcohol inter-locks is probably more difficult to handle than for both ISA and seatbelt reminders, but this depends on the design of the system.

Existing alcohol inter-locks, possible to buy on the market, are designed so that the driver needs to blow in a unit at every start of the engine and sometimes also at fixed time intervals. In order to reach high acceptability if alcohol inter-locks is to be fitted on a mandatory basis, it is probably beneficial if the systems only have a minor impact on normal driving behaviour. Some systems have been tested, like the “Sniffer”, which continuously analyses the amount of alcohol in the air of the occupant compartment. Such passive systems only have a minor impact on normal driving and are probably more likely to be accepted by the drivers.

However, for alcohol inter-locks used in company cars and in rehabilitation programmes the problem of acceptability is much lower. In Sweden several transport companies have fitted alcohol inter-locks in their vehicle fleets. In such cases the acceptability question is not a primary issue. It is often a result of the policy of the company providing an assurance of transport quality for their customers.

Alcohol inter-locks have been used in rehabilitation programmes. In these cases acceptability is not a primary issue.

9.1.2 Manufacturers’ effort

In Sweden some car manufacturers, for example, Volvo and Toyota, can fit their vehicles with alcohol inter-locks if their customers wish to do so. Some large fleet buyers have also decided to fit their vehicles with such systems.

Another manufacturer has demonstrated a system where a detector is built into the ignition key. The drivers must blow into the key before starting the car. The concept has many advantages, as a simple solution with good usage possibilities. Monitoring is a key factor for a successful program using this technology.

Ways of preventing cheating the system such as through re-testing the breath after starting have also been developed and are being further refined.

A great potential exists for implementing alcohol inter-lock systems in company cars. Companies may be the driving force to develop and implement alcohol inter-lock systems on the market due to their policies, strategies, and purchasing procedures. More than 5,000 company cars in Sweden are today equipped with alcohol inter-locks and the number is rapidly growing.

A transport company in Sweden decided to equip all their 4,000 vehicles with 16 alcohol inter-lock systems before the end of 2006. Moreover, the Swedish Driving Schools Association decided to fit all their 800 vehicles with alcohol inter-locks.

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3 ETSC. In-car enforcement technologies today.
In 2004 the Swedish government decided that all vehicles purchased or leased in 2005 or later, and intended to be used by the government administration, should be fitted with alcohol interlocks, and Volvo recently introduced a Volvo V70 Bi-fuel with an alcohol inter-lock which is intended mainly for non-private purchasers.

9.1.3 An example and how it operates

![Figure 16. Dräger Interlock XT alcolock device](image)

The Dräger Interlock XT determines the breath alcohol concentration by means of an electrochemical DrägerSensor.

The sampling system conveys a breath sample of a precisely defined volume to the electrochemical sensor. The sensor determines the ethanol content of the breath sample selectively and with a high degree of accuracy.

The sensor contains an electrolyte-soaked membrane which carries the measurement electrode and the counter-electrode. The electrolyte and the electrode material are chosen such that the alcohol to be analysed is oxidized electrochemically on the catalyst layer of the measurement electrode. The electrons released from the reaction at the electrode dissipate as current through the connecting wires to the instrument’s electronics. When the sensor current is analysed the entire electric charge generated during the electrochemical reaction is determined.

This coulometric measurement method gives the sensor a particular long-term stability, meaning that the Dräger Interlock XT has a six-month calibration interval. Towards the end of the calibration interval, the user is informed in good time on the graphic display screen.

The electrochemical sensor only reacts with high specificity to alcohol. As a result, acetone, for example, which can be found in the breath of diabetics and those on starvation diets, cannot

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4 Alcolock Dräger Interlock press release.
distort the measurement result because the ketone group does not react at the electrodes. This prevents any incorrectly positive measurement results.

During development of the Dräger Interlock XT, particular attention was paid to ensuring that the instrument would be ready for use quickly, as car drivers find long waits after switching on the ignition particularly annoying. At normal or high ambient temperatures, the Dräger Interlock XT is ready for use within just 10 seconds. Additionally, to allow a quick and reliable measurement at low temperatures too, the sensor and parts of the sampling system are heated. At -10 °C, the waiting time is around 60 seconds. The Interlock still can function at -40 °C (during the Scandinavian winter, for example) and at 85 °C (in blazing sunlight, for example).

9.1.4 Areas of application for Alcolock

There are two distinct areas in which Interlocks may be used: as a preventive measure or as ordered by a court under driver licensing law.

Installing an Interlock as a preventive measure in transport vehicles such as hazardous goods transporters, lorries, coaches and taxis can reduce accident damage and downtime, improve the image of the transport company, and make customers feel safer. In private vehicles driven by persons with a possible or recognized alcohol problem, the voluntary installation of an Interlock as a preventive measure can help the person to overcome their problem and can give considerable reassurance to partners or to parents, for example, whose children also drive a car.

The second area in which Interlocks are used is when a court or other authority orders an Interlock to be installed in the vehicles of drivers who have a history of offences due to driving under the influence of alcohol. Discussions about this type of use have recently started in Europe, too, and in some European countries preparations are currently underway to change the laws accordingly.

9.1.5 EU effort

The European Union has been conducting studies to see if it ought to be adopted throughout the EU and as a follow-up to this investigation a trial is to take place in two areas of the UK shortly. Supporters of the scheme argue that it helps to prevent repeat offences.

The EU feasibility study considered as an important item the setting of a BrAC threshold (fail level) for BAIIDs (Bax, Kärvi, et al., 2001).

The main goal of a BAIID programme should be that participants learn to separate drinking from driving. For that reason, a BrAC threshold of 0.00 mg/l would be preferable. On the other hand, the breath testing device may produce small positive test results, even if a person has not drunk alcoholic beverages.

So, for practical reasons and for the sake of legal security, a BrAC threshold of 0.10 mg/l is recommended. Depending on the national legislation of EU countries, this threshold equals a blood alcohol concentration (BAC) varying from 0.21 to 0.23 g/l.
The EU study also looked into the legal requirements and existing provisions in EU countries. BAIID programme participation can be administered under criminal law (by the courts) or under administrative law (by the licensing authority). Participants should be monitored regularly, and simultaneously the data from the BAIID data recorder should be reviewed. Monitoring and enforcing a DUI offender’s compliance with the BAIID programme requirements demands close co-operation between programme providers, the police and the programme administrative authority (probation or licensing authority).

A survey of legal requirements and provisions for BAIID programmes was conducted in eleven European countries. Although, apparently, legal aspects had not yet been thoroughly investigated by the respondents, the following essentials could be derived from the survey results:

- BAIID programmes can be integrated in existing sanctions for DUI. They can, for instance, substitute license suspension or shorten the suspension period, or they can be implemented as an accompanying measure as part of rehabilitation/driver improvement courses.

- BAIID programmes can be introduced as a general preventive measure (for all volunteering drivers, for various categories of professional drivers, etc.) or as a specific preventive measure (for DUI offenders).

- BAIID programmes for DUI offenders should, at least partly, be financed by the participants.

- Suggested BrAC thresholds (fail levels) varied from zero to the legal limit.

- Mandatory BAIID programmes are assumed to require changes in legislation, especially in traffic law.

- The predominant opinion of the respondents is that BAIID programmes constitute an effective tool in preventing drink-driving, and a good alternative for license suspension.
10. Seat belts

The seat-belt is considered to be the most important safety feature in the car. In fact, most other safety features in a car are based on the premise that a seat-belt is being used. Using seat-belts is the most effective way to avoid death or injury in a car crash.

Despite EU legislation that mandates the use of seat-belts, wearing rates vary considerably within the EU Member States, averaging 76% for front seat occupants and 46% for rear seat occupants (ETSC, 2003). Belt use in accidents is significantly lower.

Approximately 15,200 road fatalities did not use seat belts. If the belt use could be increased to 100% approximately 7,600 lives could be saved (ETSC, 1996).

10.1 Seat belt reminders

Seat-belt reminders are devices that send out a light and/or sound signal to alert the car occupant that he or she is not belted. There are different types of seat-belt reminders – some are just visual warnings while others are using both visual and auditory warnings.

Many new vehicles are now fitted with such devices. Seat-belt reminders have been developed for all seating positions in the car, but are to date most commonly fitted only for the driver seat or for both front seats. Attempts have also been made for retrofit systems to be used on the initiative of the Swedish Insurance Federation.

These are low-cost self-contained systems not interacting with the electronics of the car.

10.1.1 Life saving potential

Field trials in the USA, Australia and in Europe have proven that seat-belt reminders ensure that the occupant uses the seat-belt more frequently. A Swedish study shows that the seat-belt wearing rate was 99% in cars fitted with seat-belt reminders that fulfil the EuroNCAP specification (Folksam, 2005).

In the control group without reminders the wearing rate was 82%.

The study was conducted by studying the wearing rate in cities during normal traffic.

The percentage of driving time spent unbuckled decreased by 30% and the mean time taken to buckle the seatbelt decreased by up to 75% when the system was active.

Reminders are however only effective with regard to occupants who unintentionally forget to use their seat-belt. They are not effective for the small minority of persistent non-users.

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5 ETSC In-car Enforcement Technologies today.
A Swedish study has shown that not all reminders are equally effective (Björnstedt et al, 2001). Three different systems were investigated: reminder systems with both audio and visual signals, reminder systems with only a visual signal and no reminder system.

A total of 477 injured car drivers were included in the study. Ambulance personnel made observations regarding the use of seat-belts. Findings concluded that the reminder system with both a light and sound signal was the most effective system. The difference between vehicles equipped with reminder systems with only a light signal and vehicles without reminder system was found to be minor.

Less advanced retrofit seatbelt reminders also have a large potential for casualty reduction. A study performed by the Swedish Road and Transport Institute (VTI) has concluded that a seatbelt reminder for retrofit at driver position would reduce road fatalities in Sweden by about 7% yearly, if fitted into 2 million Swedish cars.

10.1.2 User acceptability

A Swedish study regarding the non-users’ motives for not wearing seat-belts showed that less than 1% of drivers were totally against seat-belt reminders. The majority of non-users had very favourable attitudes to seatbelts. However, the acceptability of seat-belt reminders will probably vary among the EU countries.

The majority of new cars sold in Sweden in the last years have been fitted with seatbelt reminders, and only a small number of negative responses from customers to these manufacturers and importers have been raised.

10.1.3 Manufacturers’ effort

EuroNCAP tests the crashworthiness of new cars with respect to front and side impacts and pedestrian accidents. Results are stated in terms of stars: five stars represent the best performance (four stars in the case of pedestrian ratings), zero stars the worst. In 2004 EuroNCAP started providing added point bonuses for vehicles fitted with seat-belt reminders. EuroNCAP promotes installation of seat-belt reminders by extra points for vehicles fitted with them.

The system must fulfil a series of conditions. Most of the new vehicles have reminders for the driver seat.

Of all vehicles tested by EuroNCAP since 2003, 72% have seat-belt reminders.

Seat-belt reminders for the rear seat were introduced in the Volvo S40 during the year 2004. Only a few car models are to date fitted with seat-belt reminders for the rear seat.

Compared with reminders for the front seat, rear seat systems appear more costly as they are more complicated to install.
Following a competition organised by the Swedish Insurance Federation and the Swedish Motor Vehicle Inspection Company, an inexpensive retrofit seat-belt reminder system for the driver seat is currently being developed at Autoliv.

To date no initiative has been taken for implementation in cars, but discussions have started.
PART III: COOPERATIVE SYSTEMS
Introduction

Enforcement can be seen as one of the working applications in a cooperative systems framework (according to CALM architecture (Continuous Air Long and Medium Range)). It would be interesting to find some solutions and key aspects in order to promote the deployment of enforcement within ITS architecture. Control and Information Systems may offer an overall solution towards road safety improvement using communications V2V (GNSS/CN, Wifi), and exploiting V2I under performance as much as possible (maximizing efficiency). The cooperation between the infrastructure and In-Vehicle technology in all this framework of ITS architecture and the optimization of the interaction and synergies between different systems might have incredible benefits towards enforcement methods. The consideration of the interests of all the actors involved should be taken in mind trying to maximize the cooperation and thus the benefits for all stakeholders in order to put into operation all these systems following the demands and exploiting the technological possibilities. In this line Vehicle to Vehicle communications and Vehicle to Infrastructure communications have an important role and CALM can be the basis for this.
11. In-vehicle technology

ADAS – CVIS – VI; these are all technologies that aim at the development and implementation of vehicle – vehicle and vehicle – infrastructure communication.

In this role of information/control/surveillance/punishment intelligent vehicles have potentialities for offering – for the first time – new ways for drivers and their vehicles to interact (and not just react) with a more intelligent infrastructure. And that new intelligence is due to new kinds of information that come, at least partly, from individual road users. This could maximize road safety improvements while considering user’s acceptance, and that is key for optimizing enforcement efforts (minimum punishment, quick put into operation of systems). At the same time, and thanks also to offering of added value services to the drivers, might have an influence diminishing their concerns about privacy which would eliminate many refrains to deployment.

11.1 Electronic Vehicle Identification (EVI)

During 2003 and 2004 a feasibility study under a Grant of the European Commission DGTREN was carried out. The perspective was the feasibility for an EU standardised electronic vehicle Identification concept that met the requirements of the public authorities (EVI, 2004).

11.1.1 Introduction to EVI

EVI is defined as an electronic device that allows the unique, remote and reliable communication of identifying parameters of the vehicle itself. It comprises an in-vehicle data storage element, suitable interfaces and a vehicle-to-infrastructure data communication element.

In its simplest form EVI can be understood as an electronic version of the VIN (such as the Vehicle Identification Number that is defined in ISO 3779/3780, which is a structured combination of characters assigned to a vehicle by its manufacturer for identification purposes), on the other hand it could include other important attributes required by Public Authorities such as electronic licence plate, vehicle registration and classification.

EVI is an enabler of and a building block in a range of public applications. It could potentially reduce vehicle fraud and crime, improve enforcement, and enhance the operational efficiency of Public Authorities.

11.1.2 Need for a new initiative for EVI

Until the EVI project there had been no comprehensive study of the requirements for and feasibility of an EU-wide implementation of EVI. It was acknowledged that policy-making in this field could not advance without a careful study of the full range of aspects ranging from technical issues such as in-vehicle integration, data security, communications requirements to
non-technical issues such as legal (data privacy etc), institutional (what parties, rights and obligations, etc), operational (how is it deployed and operated) and socio-political areas (general acceptance, etc).

EVI clearly offers considerable opportunities for the future of road transport across Europe. A number of important issues however needed to be investigated and resolved at a feasibility stage before technical development, demonstration and deployment activities can begin.

11.1.3 What public applications EVI could support

EVI could support and enable a broad set of public applications.

Examples include:

- **Enforcement** – EVI could improve the efficiency of enforcing traffic violations (such as speed, traffic light and bus lane violations), on both a national and cross-border level. In particular, EVI could overcome limitations with existing Automatic License Plate recognition (LPR) systems, where plates are missed which are damaged, dirty, obstructed, and from a different country. For Traffic Law enforcement this is a key issue that needs to be pursued vigorously, enabling a much more efficient operation of automated traffic law enforcement.

- **Emergency and Transit Vehicle Priority** – EVI could help provide fast and effective priority to emergency vehicles or to buses and trams within urban and inter-urban transport networks

- **Crime prevention and detection**. EVI could provide police authorities with an effective tool to track stolen vehicles – and ultimately help deter theft

- **Environmental issues** – EVI would provide a secure means to ensure that the EU end of life directive of not only vehicles but also key components can be accurately tracked and administered

In addition to the above, EVI could support other applications such as:

- **Demand management**
- **Traffic monitoring**
- **Road charging**

Within CEN TC278\(^6\) significant progress has been made on the standardisation of numbering schemes of vehicles and the interfaces of the Electronic Registration Identifier (ERI) with the roadside equipment and the in-vehicle environment.

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\(^6\) CEN stands for European Committee for Standardization and the TC 278 stands for the Road Transport and Traffic Telematics
11.1.4 Key issues included

- Application and service requirements – what should an EU-wide EVI system provide to be able to support public services and what are the requirements? Data protection and privacy – how to fully address potential concerns regarding data protection and privacy?

- Data security – how to ensure the integrity of EVI data and avoid the potential for manipulation and improper use?

- Public and political acceptance – some drivers for general acceptance are its potential capabilities to reduce crime, increase safety and to provide better traffic monitoring; how to gain the right “balance” of applications, which EVI is intended to support?

- Institutional and operational aspects – how to progress from existing methods of vehicle identification to a EU-wide electronic form of identification?

- Deployment issues – what are the different options for deploying EVI and what are the consequences for each option with respect to the requirements?

In order to achieve the consensus necessary for an EU-wide implementation of EVI, this project had to be a shared activity involving the principal interested parties, including the EU Member States, law enforcement agencies and other stakeholders concerned.

Additional information concerning EVI is annexed to this deliverable (Annex 5).

11.2 Forward Collision Warning – Following Distance Warning

The distance warning system warns both visually and with a sound that the driver is too close to a vehicle. The warning depends on how long the distance is between the vehicle and the vehicle ahead. The level of warning will switch from “safe” to “critical” as distance decreases.

Systems with auditory warnings have been proven to be effective warning mechanisms. For example, drivers understood and handled situations more quickly if the sound was like the sound of a car horn compared to a simple tone or a voice.

Driver inattention or failure to pay adequate attention to driving is the single most common cause of front-to-rear crashes. The following distance warning system was installed in trucks in the US and has the potential to reduce the rear impact with 57%.

In a field trial in Australia Intelligent Speed Adaptation and Following Distance Warning was used separately and together (Regan et. al, 2004). Both systems together had a positive effect on average speed and speed variability but FDW alone did not affect either the average speed or speed variability.

The reactions and acceptations of the system are high. Most of the participants in a field trial in Australia thought that they would use the system frequently if it were installed in their own
vehicle. They were going to use the system on freeway, rural, low traffic density, during poor visibility and at 50, 60, 80 and 100 km/h speed zones.

11.3 Reverse Collision Warning

The Reverse Collision Warning System warns the driver if s/he is likely to collide with an object behind the vehicle. Sensors in the rear bumper reveal the vehicle. The rate of warning becomes more rapid if the distance between the vehicle’s rear and the object decreases. Studies made in driving simulators indicate that the reverse collision warning system could help the driver to react more quickly (Lee et al, 2002).

Rear-end collision avoidance system with early and late warning was compared with no warning condition. The early warning system reduced the number of collisions by 81% and the late warning system reduced collisions by 50%.

11.4 Lane keeping devices

The Lane-Keeping Device is an electronic warning system that is activated if the vehicle is about to veer off the lane or the road. Lane changing represents 4 to 10% of all crashes. Studies made in the US show that the Lane Keeping Device could reduce the number of impact by 37% (Olsson et al., 2002). Times to collision during dangerous lane changes are normally much less than one second.

11.5 Night vision enhancement

The Intelligent Night Vision System is developed to avoid accidents between vehicle-pedestrian, vehicle-animal and also vehicle-vehicle at night time driving. There are two different types of night vision types – Near Infrared Radiation (NIR) and Far Infrared Radiation (FIR).

NIR sensors are active illumination and detect the radiation reflected by the object. FIR sensors operate at wavelengths that detect passive radiation emitted by objects at temperatures of 300 K. Cold objects will therefore appear dark. Systems based on FIR technology have been on the market since the year 2000. A pedestrian can be detected by using FIR infrared stereo cameras in front of the vehicle. The distance to the high temperature object will be calculated and the object will turn up on the display in the dashboard just in front of the steering wheel.

The system helps the driver to detect everything in the surrounding that emits heat (Olsson et al., 2002). Therefore critical situations beyond the normal head light range can be detected. Since the object is detected sooner with the night vision system the driver will also have more time to react.

This system has high safety potential as 50% of all traffic fatalities occur when the daylight is limited therefore this system has a high safety potential.
11.6 Drowsiness and Fatigue warning systems

The effect of drowsiness on accidents is still inadequately understood: 25% of fatal motorway accidents in Germany and 26% in France were caused by drowsiness. Drowsiness is overrepresented in single vehicle accidents: 3% of all single vehicle accidents reported by the police were fatigue related. It is however difficult to prove that the accident is caused by drowsiness.

There is no single indicator that can be used to identify drowsy driving. Therefore a combination of different measures is needed. A number of systems exist or are at different stage of development.

Kircher et al (Vehicle control and drowsiness, 2002) recommend a combination of analysis of lateral control performance and eye blink patterns. A warning system for drowsiness must be able to handle different driving behaviour and also identify several symptoms since symptoms of drowsiness are very individual.
12. Towards Wide-area communications based systems: Cooperative framework

12.1 CALM – Continuous Air-interface Long and Medium range technologies

An ongoing development project, CALM may be the perfect example of the “technology of technologies” concept, mentioned in chapter 1.2.

12.1.1 The CALM concept

The fundamental principles of the CALM concept, and the architecture and standards that embody it, is making "best" use of the resources available. The resources are the various communications media available, and "best" is defined by the objectives to be achieved and their relative cost. Flexibility, adaptability, and extensibility are the keys to its success (figure 17).

The CALM concept is therefore developed to provide a layered solution that enables continuous or quasi continuous communications between vehicles and the infrastructure, or between vehicles, using such (multiple) wireless telecommunications media that are available in any particular location, and have the ability to migrate to a different available media where required. Media selection is at the discretion of user determined parameters.

CALM Service Types fall into two categories: safety and commercial, although some safety related services are of commercial interest as options on up market vehicles.

The advantages of CALM are:

- CALM combines multiple communication media in an open way
- IPv6 basis means that it is fully compatible with Internet services
- Spanning multiple media, and open to more medias both broadcast and others – by the integration of a simple IPv6/Management convergence layer
- CALM is based on well-tested standards and media that are adopted and optimized for the mobile environment. This means:
  - Low risk strategy
  - Fast and relatively low cost implementation
  - Much of the infrastructure and service network is already available
  - Allows new media to be easily introduced
CALM includes the spectrum protected, 5GHz low-latency vehicle-vehicle / vehicle-roadside communications system needed for many vehicle-based public safety systems. This is one of the findings of the recently concluded ESafety project.

Supplements DSRC (European dedicated short range communication) with possibilities for higher speeds.

Co-operation with ITS standardization Working Groups and with ETSI.

The scope of CALM is to provide a Standardized set of air interface protocols and Parameters for medium and long range, high speed ITS communication using one or more of several media, with multipoint and networking protocols within each media, and upper layer protocols to enable transfer between media (figure 18).
Figure 18. CALM architecture
### 12.1.2 CALM-enabled safety services

Table 7. Calm enabled Vehicle2Infrastructure safety services

<table>
<thead>
<tr>
<th>Vehicle &lt;&gt; Infrastructure</th>
<th>Infrastructure</th>
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<tr>
<td>w Animal Crossing Zone Information</td>
<td>w Low Bridge Warning</td>
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<tr>
<td>w Adaptive Headlight Aiming</td>
<td>w Low Parking Structure Warning</td>
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<tr>
<td>w Blind Merge Warning</td>
<td>w Merge Assistant</td>
</tr>
<tr>
<td>w Curve Speed Warning</td>
<td>w On Board VMS signage</td>
</tr>
<tr>
<td>w Emergency Vehicle Signal Pre-emption</td>
<td>w Open Road (no barrier) Tolling</td>
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<tr>
<td>w Emergency Vehicle Video Replay</td>
<td>w Pedestrian Crossing Information</td>
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<tr>
<td>w External Speed Limitation</td>
<td>w Pedestrian/Children Warning</td>
</tr>
<tr>
<td>w GPS Corrections</td>
<td>w Post-Crash Warning</td>
</tr>
<tr>
<td>w Highway/Rail Collision Warning</td>
<td>w Right Turn Assistant</td>
</tr>
<tr>
<td>w Homeland Security Identification and Management</td>
<td>w Road Condition Warning</td>
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<tr>
<td>w Incident Mapping and Warning</td>
<td>w Rollover Warning</td>
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<tr>
<td>w Infrastructure Intersection Collision Warning</td>
<td>w School Zone Warning</td>
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<tr>
<td>w Intelligent On-Ramp Metering</td>
<td>w Sign information (warning assistance)</td>
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<tr>
<td>w Intelligent Traffic Lights</td>
<td>w SOS Services</td>
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<tr>
<td>w Intersection Collision : Infrastructure-Based Warning</td>
<td>w Speed Limit Advisory</td>
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<tr>
<td>w Intersection Collision : Vehicle-Based Warning</td>
<td>w Stop Sign Movement Assistance</td>
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<tr>
<td>w Keep Clear Warning</td>
<td>w Stop Sign Warning</td>
</tr>
<tr>
<td>w Left Turn Assistant</td>
<td>w Traffic Signal Warning</td>
</tr>
<tr>
<td>w Right Turn Assistant</td>
<td>w Vehicle Safety Inspection</td>
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<tr>
<td>w Road Condition Warning</td>
<td>w Work Zone Warning</td>
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<tr>
<td>w Rollover Warning</td>
<td>w Wrong-way Driver Warning</td>
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Table 8. CALM enabled Vehicle2Vehicle safety services

<table>
<thead>
<tr>
<th>Vehicle &lt;&gt; Vehicle</th>
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<tbody>
<tr>
<td>w Approaching Emergency Vehicle Warning</td>
<td>w Intersection Collision: Vehicle-Based Warning</td>
</tr>
<tr>
<td>w Blind Merge Warning</td>
<td>w Lane Change Assistant</td>
</tr>
<tr>
<td>w Blind Spot Warning</td>
<td>w Left Turn Assistant</td>
</tr>
<tr>
<td>w Cooperative Adaptive Cruise Control</td>
<td>w Merge Assistant</td>
</tr>
<tr>
<td>w Cooperative Collision Warning</td>
<td>w Pre-crash Sensing</td>
</tr>
<tr>
<td>w Cooperative Glare Reduction</td>
<td>w Post-Crash Warning</td>
</tr>
<tr>
<td>w Cooperative Vehicle-Highway Automation System (Platooning)</td>
<td>w Right Turn Assistant</td>
</tr>
<tr>
<td>w Crash Warning</td>
<td>w Road Feature Notification</td>
</tr>
<tr>
<td>w Curve Speed Warning</td>
<td>w SOS Services</td>
</tr>
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<td>w Enhanced Differential GPS Corrections</td>
<td>w Stop Sign Movement Assistant</td>
</tr>
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<td>w Highway Merge Assistant</td>
<td>w Vehicle-based Road Condition Warning</td>
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<td>w Highway/Rail Collision Warning</td>
<td>w Vehicle-to-Vehicle Road Feature</td>
</tr>
<tr>
<td>w Hybrid Intersection Collision Warning</td>
<td>w Notification</td>
</tr>
<tr>
<td>w Instant (Problem) Messaging</td>
<td>w Vehicle Platooning</td>
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<td></td>
<td>w Visibility Enhancer</td>
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<td></td>
<td>w Wrong-Way Driver Warning</td>
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12.2 Mature technology for ITS: DSRC (Dedicated Short Range Communications)

Relying on short-range microwave communications between vehicles and roadside receivers and transponders, DSRC is commonly used to determine when vehicles enter or exit specific road segments or geographic areas. DSRC may also be used to assist in enforcement, for instance by verifying that a passing vehicle has a functioning on-board unit that is registering and communicating the data required by the particular application (figure 19).

12.2.1 The technology

These systems need road-side equipment, typically mounted on a gantry, with electronic tags in the vehicles which may be read-only, read–write or smartcard-based (Tully, Blythe, 2005). Read-only tags contain a fixed identification code which, when interrogated by a roadside reading device at the charging point, conveys this identity to the roadside system. The code relates to the identity of the vehicle or the identity of the user’s account. Read-only tags operate reliably only if used for single-lane operation at low speed and over a short range. However, their inflexibility, dumbness, and inability to work in a high-speed, multi-lane road situation limit their application to that of automating existing toll-plazas. Read–write tags are a logical development of the read-only tag. They can receive data from the roadside and store this data directly on the tag or on a separate value-card (which may be interfaced to the tag whilst in the vehicle). The most flexible in-vehicle units (IVUs) are transponders (smart tags) that support smartcards. They are intelligent, having the capability to handle and process many kinds of...
data and to be programmed to manage a number of different applications. Such a system requires a reliable, high-speed two-way data-communications link with the roadside and more complex on-board equipment, replacing some of the processing requirements traditionally handled by the roadside equipment.

The transponder is designed following a modular approach, thus facilitating later implementation of add-on peripheral equipment (e.g. smartcard readers, keyboards, displays and connections to other in-vehicle equipment). Such transponders were first developed in the EU funded project ADEPT (automatic debiting and electronic payment for transport) project in the early 1990’s, a European funded project led by TORG in the early 1990s which installed trial systems in the UK, Sweden, Portugal and Greece.

The modularity in the design of the automatic debiting transponder prototypes allows several different forms of payment (all of them cashless) with one device. Possession of a transponder offers users the possibility of holding a positive (or a limited negative) balance of credit-units, either directly in the transponder’s memory or alternatively on a separate smartcard interfaced to the transponder. The smartcard, being portable, can then be used for other payment purposes. These systems are perceived by many international road administrations as the future of road-user charging, where high-volume, multi-lane roads need to be tolled without restricting traffic flow. Europe standardisation of DSRC systems nears completion and many products based upon 5.8 GHz microwave communications technology will soon emerge, though to date few commercial installations exist. Worldwide, the Singapore system and Highway 407 in Canada utilise such an approach. The key limiting factor seems to be the processing speed of the smartcard – in Singapore, each charging point has two gantries – one to start communications with the vehicle and a second (further down the road) to complete the transaction and perform enforcement measures, if necessary. The demonstration of interoperable road-user end-to-end charging and telematics systems (DIRECTS) project, launched by the Department for Transport (DfT) using 800 or so volunteer drivers, who will
have their vehicles equipped for the trial in Leeds, will finally prove an end-to-end solution for DSRC-based charging. The aim of DfT is to develop a UK national specification for Interoperable payment of road-user charges, consistent with the emerging European standards.

Also known as MPS (Mobile Positioning System), these systems make use of different technologies for to accomplishment of two basic functions:

- Establish the precise location – or any other feasible parameters – of a given vehicle
- Establish a two-way communications link between the vehicle and a ground-based installation for the exchange of relevant data

Up to this day, the technologies that have been used most to make these functions have been GPS satellite based location system and GSM for communications, but a number of new technologies can be also used for these purposes and will also be briefly explained here.

### 12.3 GPS – Global Positioning System

GPS is a satellite-based system, devised by the US military, for determining latitude and longitude on the surface of the earth. GPS receivers (integrated with the on-board unit) can be used to determine location within the road network, speed of travel, time of travel, and distance of travel. It is worth noting that in 2008, the European Union intends to launch a similar satellite based positioning system called Galileo, which may ultimately be used within the various European projects. For the sake of simplicity, however, the term GPS could be used to generically refer to any satellite-based location technology.

One of the most interesting aspects of GPS is that it can be applied at various resolutions, depending on what the needs for a given system may be.

In road charging systems, GPS at its broadest level can be used to determine whether a vehicle is inside a given geographic area. At a more accurate level, it can be used to check whether a vehicle is in a given road or class of road. Finally, GPS could be potentially used to detect the presence of vehicles in specific lanes within a road, though it has to be said that there are still accuracy limitations to successfully implement this kind of GPS applications.

### 12.3.1 Limitations of GPS

*The effectiveness of GPS depends on the level of accuracy required*

The degree to which GPS yields “accurate” measurements is related to the scale of the data being represented. If the goal is to determine merely whether the vehicle is in one charging zone (e.g., a state) or another, current applications of GIS are easily adequate. If the goal is to discern one road from another, accuracy is a much larger issue. For example, to distinguish between a freeway and a parallel frontage road, accurate position measurements to within

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7 Sorensen, Taylor, 2005
roughly 20 meters are required. With differential correction, GPS can typically measure location to within one or two meters, which is quite sufficient to meet the task.

Unfortunately, to correctly match a geographic position to a segment of the road network, it is also necessary to have accurate digital road network maps, and this is where the problem lies. Researches have demonstrated that most commercially available digital road maps fail to provide 40 meter accuracy with consistency, and this makes it difficult to distinguish between closely situated parallel roads. The implication is that in any program that seeks to differentiate pricing based on road segment or road class, great care (and possibly great expense) must be devoted to constructing sufficiently accurate road network maps.

**GPS does not always work properly and thus should be supplemented**

GPS can suffer a number of problems, including loss of battery power, and intermittent loss of signal due to tall buildings, tunnels, or even the roof of the vehicle. It is therefore appropriate to supplement GPS systems with some other backup technologies during the times when the GPS is not available.

### 12.4 GSM – Global System for Mobile communications

A satellite-based cellular communications system, it could be used as an alternative or in conjunction with other technologies. While typically more costly than DSRC, GSM does not require the installation of roadside equipment, and it permits real-time communications, as opposed to DSRC, where transmission of data is only possible when the vehicle drives by a roadside receiver.

One of the problems of GSM is that its communications are transmitted over a much longer distance than in any other technology, and thus the risk of unauthorized data interception increases.

### 12.5 3G Cellular Radio technologies

Until recently, mobile phones could not be used for positioning, because they did not provide enough accuracy of where the unit is at any given time. Third Generation (3G) mobile devices and networks, on the other hand, may have a native locating function, which, companies claim, provides a 10-15m resolution, which would be enough for most traffic enforcement purposes.

As the phones already have secure access and a central payment facility, as well as European-wide interoperability, this technology could prove a serious piece in enforcement strategies.

### 12.6 Future evolution: 4G technologies

In the near future, with the rapid evolution of communications’ and networking technologies may cause a change in the way vehicle-to-vehicle and vehicle-to-infrastructure communications are conceived. The focus is now on 4G systems, which will not be
technologies in themselves, but rather an integration of existing technologies such as 3G, DAB (Digital Audio Broadcast) and WLAN (Wireless Local Area Network) into heterogeneous wireless networks to provide access to an ever increasing range of services.

Data could be transported through 4G networks using packets which conform to the Internet Protocol version 6 (Ipv6) standards. Mobile devices will be able to connect to a 4G network through the nearest WLAN hotspot Access Point (AP). The ability for mobile devices to access generic services via WLANs will mean that users become totally independent of the mobile network operator. There is no longer any need for a stovepipe solution for charging. Local authorities and transport operators seem to favour this technology as a short to medium term solution for personal communications provision over LAN distances.

12.7 Some project results: CVIS (Cooperative Vehicle-Infrastructure Systems)

The CVIS (Cooperative Vehicle-Infrastructure Systems) FP6 Integrated Project aims to develop and test new technologies to allow road vehicles to communicate with any nearby roadside infrastructure. Based on such real-time road and traffic information, many novel applications can be produced.

The consequence will be increased road safety and efficiency, and reduced environmental impact.

The project’s ambition is to start a revolution in mobility for travellers and goods, completely re-engineering how drivers, their vehicles, the goods they carry and the transport infrastructure interact and cooperate.

This can only work if different makes of vehicle and different types of roadside system all use the same communication standards. CVIS will therefore develop a world “first”: a mobile router to link vehicles continuously with roadside equipment and servers. The project will apply and validate the ISO “CALM” standards for continuous mobile communication, and will provide input to standards development in European and global standardisation bodies. More information on CALM standards is provided in part III of this document.

Other key innovations include high-precision positioning and local dynamic maps, a secure and open application framework for access to online services and a system for gathering and integrating monitoring data from moving vehicles and from roadside detectors and sensors.

These technologies will be developed for selected urban, interurban and freight/fleet applications, and tested at test sites in France, Germany, Italy, Netherlands/Belgium, Sweden and the UK.

Finally, the CVIS project is creating guidelines and tools to address key technical and non-technical issues for deployment.
12.7.1 CVIS technologies

The fundamental enabling technology for cooperative systems is a “universal communications module” that can interface to existing in-vehicle systems, and to existing roadside installations, and that can maintain a continuous wireless high-capacity data channel (figure 20).

The CVIS module can use existing bearers such as 2.5/3G cellular phone and DSRC, and will be specifically designed for the new “Wi-Fi for mobiles” wireless local networking supporting both vehicle to vehicle and roadside infrastructure communications.

This means that an operator, service provider or other nearby vehicle will be able to address a vehicle in entirely new ways, such as by location or by IP address, and provide new kinds of service.

Traffic management systems will be able for the first time to communicate with individual vehicles, and to optimise the network efficiency in the knowledge of every vehicle’s position and trajectory, and even its desired destination.

This opens the way to provide personalised routing guidance using instantaneous traffic information, safety alerts to vehicles in a certain area and speed recommendations to groups of vehicles.

This will increase total network capacity and reduce localised congestion, thus also reducing the number of accidents. Traffic will flow more smoothly with fewer stops, thus improving air quality.

Special priority can be given to classes of vehicles, such as emergency or public transport vehicles, or goods vehicles.

Drivers will benefit from more complete and up-to-date information about traffic hazards and congestion, presented in new ways – for instance road signs, variable message signs and traffic
light status can be displayed in the vehicle. Through new interfaces drivers will be able to exchange requests and recommendations.

The “always-connected” communications channel will allow access to information and entertainment content available on the Internet, and to interact (in safe ways) with home and office.

These possibilities will be available thanks to above introduced CALM framework. This project will serve as a demonstration about specific applications that can be supported and therefore have some first hand results through trial implementations in various countries.

12.7.2 Needs for cooperation among stakeholders

A significant change in policy thinking requires important challenges to be addressed in order to exploit this presented capability that allows to link vehicles to the roadside and to each other. Once this milestone is reached this presented availability of seamless communication channels might put into use the huge range of opportunities for far-reaching innovations in the way the road network is used.

It is clear that the complexity of CVIS policy environment creates a major challenge. There must be co-ordination between those who have a policy influence in all those areas. The institutions and mechanisms to achieve this have yet to be devised and put in place.

This must be addressed or a lack of policy and policy co-ordination could become a significant barrier to deployment.

12.7.3 Objectives

The CVIS objectives are:

- to create a unified technical solution allowing all vehicles and infrastructure elements to communicate with each other in a continuous and transparent way using a variety of media and with enhanced localisation
- to enable a wide range of potential cooperative services to run on an open application framework in the vehicle and roadside equipment
- to define and validate an open architecture and system concept for a number of cooperative system applications, and develop common core components to support cooperation models in real-life applications and services for drivers, operators, industry and other key stakeholders
- to address issues such as user acceptance, data privacy and security, system openness and interoperability, risk and liability, public policy needs, cost/benefit and business models, and roll-out plans for implementation.
12.7.4 Key Project Results

Within the main blocks of Core Technologies, Cooperative Applications, Test Sites and Deployment Enablers, the CVIS sub-projects will produce the following key results:

* a multi-channel terminal capable of maintaining a continuous Internet connection over a wide range of carriers, including cellular, mobile Wi-Fi networks, infra-red or short-range microwave channels, ensuring full interoperability in the communication between different makes of vehicle and of traffic management systems

* an open architecture connecting in-vehicle and traffic management systems and telematics services at the roadside, that can be easily updated and scaled up to allow implementation for various client and back-end server technologies *(figure 21).*

* techniques for enhanced vehicle positioning and the creation of local dynamic maps, using satellite positioning, radio triangulation and the latest methods for location referencing

* extended protocols for vehicle, road and environment monitoring to allow vehicles to share and verify their data with other vehicles or infrastructure nearby, and with a roadside service centre

* application design and core software development for

* cooperative urban network management, cooperative area destination-based control, cooperative acceleration/deceleration and dynamic bus lanes

* enhanced driver awareness and cooperative traveller assistance on inter-urban highways

* commercial vehicle parking and loading zones booking and management, monitoring and guidance of hazardous goods and vehicle access control to sensitive areas

* deployment enabling toolkit in the form of models, guidelines and recommendations in the areas of openness and interoperability; safe, secure and fault-tolerant design; utility, usability and user acceptance; costs, benefits and business models; risks and liability; cooperative systems as policy tool; and deployment road-maps
CVIS and its USA counterpart VII (Vehicle – Infrastructure – Integration) may offer promising progress in the area of passive enforcement if addressed properly.

The strong point of CVIS for passive enforcement will be the continuous communication link. SpeedAlert and ISA (described in the beginning of this deliverable) could be integrated in this concept. Not only for compliance with speed limits, but a whole range of compliance issues turn up here, for instance:

- Intersection collision avoidance.
- Prohibited overtaking.
- Closed lanes (related to time and/or categories of vehicles).
- Tailgating.
- City limits/city centre access.

![Figure 21. CVIS architecture](image)
12.8 Other projects results

12.8.1 SAFESPOT

The SAFESPOT Integrated Project aims to understand how intelligent vehicles and intelligent roads can cooperate to produce a breakthrough for road safety.

The aim is to prevent road accidents developing a “Safety Margin Assistant” that:

- detects in advance potentially dangerous situations,
- extends “in space and time” drivers ‘awareness of the surrounding environment

The Safety Margin Assistant will be an Intelligent Cooperative System based on Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication.

- Some application scenarios are the following:
  - Safe lane change manoeuvres
  - Road departure prevention
  - Cooperative manoeuvring (e.g. highway merging)
  - Cooperative tunnel safety
  - Hazard and incident warning
  - Safe urban / extra urban intersections

12.8.2 COOPERS (CO-OPerative Systems for Intelligent Road Safety)

Co-operative networks for intelligent roads - Infrastructure to Vehicle Communication (I2V)

COOPERS is focused to the application of a real time data communication between infrastructure and vehicle to exchange safety related information (e.g. speed, road conditions, lane change by passing, local traffic conditions, etc.) with respect to the actual conditions of a certain road segment.

12.8.3 SeVeCom (Secure Vehicular Communication)

Vehicular communications (VC) and inter-vehicular communications (IVC) bring the promise of improved road safety and optimized road traffic through co-operative systems applications. A number of initiatives have been launched, such as the Car-2-Car consortium in Europe, or the DSRC in North America. A prerequisite for the successful deployment of vehicular communications is to make them secure. It is essential to make sure that life-critical information cannot be modified by an attacker; it should also protect as far as possible the privacy of the drivers and passengers. The specific operational environment (moving vehicles, sporadic connectivity, etc.) makes the problem very novel and challenging.

Sevecom will focus on communications specific to road traffic. This includes messages related to traffic information, anonymous safety-related messages, and liability-related messages.
13. Future and obstacles: Efficiency of digital video for enforcement and privacy/data security requirements

13.1 Key solution for most applications: ANPR – Automatic Number Plate Recognition

Figure 22. General scheme of an ANPR-based speed enforcement system

Video-based systems rely on the accurate reading of vehicle licence plates as the primary means of identifying vehicles in an automated enforcement scheme (Tully, Blythe, 2005). The big advantage of this is that it obviates the need for any in-vehicle equipment. Automatic number plate recognition (ANPR) is a variation on the automatic account identification system, which also relies on the vehicle’s number plate as its unique identifier. ANPR systems process the video images taken by a camera at the roadside or on a gantry, locate the number plate in the image and convert this into the appropriate alphabetic/numeric characters, without any human intervention.

The increasing use of video cameras for road traffic monitoring has given an incentive to improve camera technology, including optical processing, to provide a wider contrast range and give clear images, even when the licence-plates are in heavy shadow or surrounded by bright headlights in direct alignment with the camera. Unresolved problems with ANPR, however, still include:

- Number plates of many and different shapes and sizes
- Difficulties in accurate reading under poor weather conditions – e.g. due to dirt/rain/snow
Similarities between some letters/numbers (Os being read as Ds, for example) and

Insufficient control of ambient light at camera positions

To improve the overall accuracy, some vendors provide for the capture of multiple images. If ANPR system determines the same plate information for all images, the confidence level of the data is improved and manual interpretation may not be required. Any discrepancies are either placed in a queue for visual inspection or treated as a lost revenue transaction.

13.2 ANPR implementation possibilities and problems

In the overall ANPR scheme, there are several areas in which different implementation options are possible.

- Digital camera
- PC hardware for all computations and data transfers
- PC software based on a general purpose operating system (OS)
- Software development based on tools provided by a general purpose OS
- Data transmission via networks.

Any of these areas open interesting possibilities to the development of enforcement equipment and software, but also pose challenges in terms of definitions to comply with general requirements of enforcement systems. Not any off-the-shelf OS is qualified for secure data processing, open networks provide potential attack and interference points, etc.
As an example, design requirements for the evidential record via image could be:

- The camera shall have an angle of view sufficiently to ensure that the speeding vehicle is clearly identified in relation to the measuring position and other vehicles, if they possibly have influenced the measurement.

- The record file shall include the following:
  - a. Image (or images) of the offending vehicle and its license plate
  - b. Image of the driver in the states where required
  - c. Date in day, month and year
  - d. Time in hours, minutes and seconds
  - e. Location
  - f. Measured speed
  - g. Direction
  - h. Any additional data required by the local enforcement authorities. In the case of Spain there is the need of providing univocal camera reference for acquisition of data.

Similar design requirements should have to be drafted for the remaining components and software of the system.

### 13.3 Protection of data

As in other sensitive electronic environments, protection of data is a crucial aspect of an automated enforcement system (Jäger, Lagauterie, et al.). Privacy concerns have been used as an argument in many Member States so that particular types of automated enforcement systems implementations have been hampered or slowed down. When it was not privacy, it was the somewhat shady legal objection of taking pictures of citizens before it was known whether any infraction had been actually committed, as pointed out before in this paper. Finally, security issues arise concerning the integrity and authenticity of the data files used throughout the process, and then the fear that third parties may tap the information and use it for purposes other than enforcement. The list of security objections posed could go on for a while.

- Research has shown that the three areas that have been considered as the most critical.
- Protection of data files to insure integrity and authenticity
- Protection of data and software of the equipment against changes
- Conformity of each batch produced device with the approved type

There have been proposals for an EU Directive addressing these particular areas as a necessary step towards standards harmonization across EU. This step has already been taken with regard to other measurement devices with equal legal and enforcement-related consequences – tachographs, taximeters, etc.
In these drafts, the same potential risk areas have been identified, and the solutions proposed are roughly the same in any case, always taking into account the current state of electronic security data communications.

13.3.1 Data integrity and authenticity – Digital Signature

For guaranteeing integrity (information not changed) and authenticity (origin known and correct) of data acknowledged algorithms and infrastructures are available.

One of the common schemes for the protection of sensible data like digital enforcement data is a public key system. This allows to store data on a removable media where anyone can access it (or even try to modify it) or to transfer the data via a communication line. In a public key system a pair of keys exists where one of them is secret, i.e. it is stored inside the measuring instrument and cannot be read, and the other one is public. In fact the pair is generated within the instrument so no person will ever have to input the secret key and thus be able to compromise it. The secret key is used for generating the electronic signature of the data set consisting of image and measured data. A specific program in the office verifies the signature and displays the result (a symbol easy to recognise) together with the image and measured values.

Securing the data set with a digital signature on the basis of a public key system requires the following procedure for each data set:

- A hash code of the data set is calculated
- This hash code is encrypted with the secret key
- The encrypted hash code is used as a signature and appended to the data set
- The data set is transferred to the processing site
- Once received, the integrity and authenticity of the data set is verified:
  - The hash code of the data set is calculated using the same algorithm of the measuring device
  - The signature is decrypted with the public key corresponding to the particular measuring device which originated the data
  - The result of this decryption has to be equal to the calculated hash code in the first step. If it is not, either the data set has been modified (integrity failure) or there is a mismatch between the private and public keys used to encrypt and decrypt the signature (authenticity failure).
  - If both the integrity and authenticity of the data set are proven, the procedure for processing of the data –infraction or violator’s identification by video processing, etc.- may continue. Otherwise, data set is discarded.
Some other details concerning digital signature are:

- Algorithms with accepted quality for hashing are, for example, SHA-1, RipeMD160 or MD5

- Acceptable algorithms for public key systems are RSA with a key length of 1024 bits, or one based on elliptic curves with a key length of 160 bits. A regular review of the latest accepted algorithms is advisable.

- The public key that has been concurrently created with the private key may be shown on the display of the data originating device or printed. Display directly on-site proves all more easily the valid origin of the data (principle of “Direct Trust”), while the impossibility to read and register the public key directly at the decide site will require the involvement of a “Trust Centre” which attests the origin of the key.

- Encryption of the complete stored data (not only the hash code) may be required to prevent unauthorised access and abuse and to ensure confidentiality additionally to integrity and authenticity. For this purpose, however, faster algorithms with lower protection level may be appropriate (depending on the level of privacy required by national legislation).

- If the storage media with the relevant information of the offence is archived, it is possible to repeat the presentation of the measurement result and the accompanying information, the proof of integrity and the proof of the alleged origin (location) at any time. Precondition is the availability of an unchanged copy of the office program. Such a copy should be kept in a trustworthy institution, usually the authority responsible for type approval. This copy can then be used in case of doubt (e.g. in a trial at court). Therefore it may be allowed to use a normal off-the-shelf personal computer in the office.

- This procedure offers an expert at court the possibility to check the integrity and authenticity of a data file containing the image data and the measured values even if the file has been transferred via open networks. In case of doubt he can get the public key from the verification authority and the necessary program from the type approval authority.

### 13.3.2 Protection against unauthorized access to the software

If the system is connected to a network prepared for bidirectional data transfer an additional threat has to be taken into account. The relevant data are stored only temporarily inside the measuring device. On command or automatically the data set is transmitted via network to the corresponding processing centre. All securing means like signing and key management may be the same as described above.

Remote control of devices from a central coordination centre has some advantages. It may be useful to control camera functions or to dynamically set thresholds for triggering the measuring device, or otherwise perform some kind of data maintenance operations.
These are not legally relevant operations, and therefore, could be subject to less strict security and approval requirements, making thus easier a future upgrade of the software under which these operations take place, for example. This requires different parts of the software to be clearly differentiated and separated, with clear definitions as to data access, user access, functions to perform on which data, and so on.

A possible implementation may have three different software parts, each with its own authorization and security requirements and procedures.

- The first part comprises all legally relevant functions, data and parameters. This part is protected against changes of the programs and the critical configuration parameters, using maybe some of the technologies mentioned before or using additional physical measures. This part is what EU Directive draft on software of speed measurement systems may declare as fixed on type approval, with exhaustive analysis on source code, documentation and tests to make sure that the functions to be performed by this part of the program guarantee the high level of security required (i.e. complies with the highest levels regarding integrity, authenticity and, when necessary, confidentiality of the data generated and transmitted).

- The second part comprises functions and data that have no influence on the legally relevant functions – for example, controlling camera parameters. In this part parameters could be change from the “outside” because protection is not necessary from a legal point of view.

- The third part could be a buffer containing data files that are already protected by signature. This part could be open for external access.

In turn, these requirements make it necessary the use of an operating system which supports separation and protection of domains and of the communications between these domains – UNIX, for example.

With this domain-separation in mind, and going back to the three-part scheme mentioned before, programs in the first part or domain would have full rights to read and write data and execute functions in any other domain of the system. Programs in the other domains will have restricted or no access at all to functions or data in the first domain. The restrictions are part of the operating system architecture, which may use a password scheme to make the legally relevant first domain inaccessible by unauthorized users.

It is also interesting noting that the same configuration described –three different parts with different sensitivities regarding the functions and data in them and therefore different access restrictions- can be viewed itself as part of the first domain, in the shape of configuration and script files. This means that the whole configuration is unchangeable and protected, and its definition therefore subject to the same strictest examination at type approval.

But once approved, this scheme allows for a secure environment using a universal computer, in which properly authorized users may perform legally relevant operations and data transmissions with confidence, and still leave room for routine maintenance operations and even upgrades of the software taking care of these operations with minimum restrictions.
14. Conclusions and future work

Legal frameworks, privacy issues, user acceptance, type approval of enforcement equipment, specification of data for describing the event, certification, interoperability, cross border implementations, benefits after implementation and collateral effects (cost effectiveness, mobility, environmental aspects) are issues still to be given further treatment in order to promote real deployments in any Member State.

There are several aspects that are still open to research in this framework.

Firstly, technological availability in communication systems and digital video field exists. It can be either included as part of road infrastructures either as part of smart vehicles. There are quite a number of functions and applications this serves for and each of those gives solution to different, although usually closely linked, purposes for which the difference sometimes is only a question of requirements and lack of cooperation between main stakeholders.

Besides, the objectives are quite clear and connected as well: those are safety, cost-effectiveness, mobility, security, environment and even intermodality if traffic management is properly considered in this framework of information/warning and support, monitoring/surveillance and enforcement.

Alongside with that, the issues that have to be resolved, hopefully in the near future, are the following:

- The specification of an adequate standardisation framework that allows the interoperability of technologies in different contexts and countries.
- The integration in the architecture provided by CALM (communication media).
- In the specific context of Traffic Law Enforcement, type approval of equipment used in automated procedures and description of data that univocally describes the potential offence in order to give it a validity in any MS, regardless the legal, jurisdictional and socio-political context and the privacy issues that have to be respected. Always respecting the proper data security needs in this delicate context where personal information is being addressed.
- The automation of enforcement measures has the potential of improving considerably cost-efficiency of the systems through alleviation and optimization of manual work.
- More emphasis should be given to prevention and warning measures in order to optimize enforcement efforts and minimize punishment work when other options would be sufficient in order to improve traffic safety. In this line it should be given the deserved importance to deterrence effect achieved by control and surveillance and also the importance of giving some initiative to the driver. Those accidents caused by lack of traffic information or distraction would not need punishment in the first place.
- For driver support/monitoring systems the importance of user needs and acceptability should be a priority in the design of tools. Training and warning to the drivers might
increase this considerably in the first term, and this goes alongside with the above presented issue (chance to act, not only to react). Besides, this might be increased thanks to the integration of personalised traffic information to support the provision of commercial added value systems in the same applications thanks to the possibilities of last generation communication systems (broadband, long range and secure, in order to perform electronic transactions through them)

w Cooperation might be the key towards this safety and mobility goal fixed by the EC in European roads. This would promote the put in operation of systems.

w As a final conclusion and idea for next steps: further research must be performed in an overall framework in relation with the following issues:

w Time critical applications,

w Mechanisms for safe and secure application management

w Deployment related issues (organization issues)

To sum up, it is important at least to put into operation automated systems that are not too complicated but guarantee the requirements and quality expected in order to be able to perform studies on the real impact on safety and establish the guidelines for best practises and solutions to be promoted and deployed in any Member State.
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17. Annexes
Annex 1.

PACTS Research briefing on speed camera myths

INTRODUCTION

Since their introduction, speed cameras have consistently proven to be a remarkably cost effective and successful method of reducing casualties on the roads. In recent months, however, there have been a number of critical reports in the media branding speed cameras a ‘failure’. This research briefing – prepared by the Parliamentary Advisory Council for Transport Safety and the Slower Speeds Initiative – reviews 10 of these criticisms of cameras and examines the research evidence surrounding them. The results reveal that many of the criticisms are either unfounded or seriously flawed and do not accurately represent the majority of research evidence.

1 CAMERAS COST LIVES

Claim: Autocar and others have claimed that ‘speed cameras cost lives’, by pointing to the declining rate of reducing fatalities on the roads in the past ten years, compared to the previous ten years. The Association of British Drivers (ABD) has claimed that 5,500 lives have been lost as a result of speed cameras in the past 10 years.
**Reality**: There is no evidence and no logical reason to suggest a correlation between the advent of speed cameras and the declining rate of road casualty reduction. Research has consistently shown that speed cameras have a major impact in reducing casualties. A major two-year DfT study of speed cameras across six areas found a 35% reduction in people killed and seriously injured at camera sites, compared to long-term trend. This finding repeats results of previous studies: the West London Speed Camera Demonstration Project experienced casualty reductions of 55% compared to control sites and 70% compared to the period before cameras were installed.

Similar findings have emerged from other countries: an evaluation of 28 camera sites in New South Wales, Australia found a reduction in fatalities from 21 in the three years before camera installation to 1 in the two years after installation.

Some critics of cameras have disputed the DfT study, arguing that the 35% reduction in casualties at camera sites represents a ‘regression to the mean’ or a return to long-term casualty trends. However, a study by Imperial College of the impacts of speed cameras over a twelve year period in Cambridgeshire enabled researchers to eliminate the effects of regression to the mean. It concluded that cameras can reduce collisions involving injury by ‘an astounding 45.74%’ with ‘lower but still significant decreases’ within a 2 kilometre radius of a camera. The results also demonstrated that speed cameras do not increase crashes by leading to abrupt braking in the vicinity of cameras.

Despite the positive impact of speed cameras on road casualty figures, however, the steep decline in road fatalities achieved in the 1980s has not been matched by the more gradual drop in fatalities in recent years. This is a concern for everyone involved in road safety, and further action should be taken to reduce the number of road fatalities.

Sharp reductions in the number of road deaths were achieved between 1983 and 1993, and have been largely associated with the 1983 law making front seatbelt wearing mandatory, better car design and major reductions in drink driving fatalities. Factors likely to be responsible for the slowing rate of reduction between 1993 and 2003 include continued increases in traffic (up from 583 billion passenger kilometres 1993 to 634 billion passenger kilometres in 2002); sharp increases in motorcycle casualties (up from 427 in 1993 to 609

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in 2002\(^ {14}\); a levelling-off of drink drive fatality numbers (up from 520 in 1993 to 560 in 2002\(^ {15}\)); a decline in seatbelt-wearing and the increased use of mobile phones while driving. The factors contributing to the slowing rate of fatality reduction are currently under review as part of analysis of progress towards targets for 2010 casualty reduction set out in the road safety strategy.

Other indicators show a somewhat more positive picture of declining road casualties. The casualty rate – the number of people killed or seriously injured per million vehicle kilometres – has fallen from 74 in 1993 to 62 in 2002\(^ {16}\). The number of serious injuries per year has fallen by over 9,000 (or 20%) since 1993.

## 2 SPEED IS NOT A MAJOR FACTOR IN ROAD CASUALTIES

**Claim**: The ABD and other opponents of speed cameras claim that ‘speed doesn’t kill’\(^ {17}\) and reject the relationship between speed and the frequency of road crashes.

**Reality**: Road safety literature overwhelmingly supports the relationship between speed and both the frequency and severity of crashes. Crash investigations have established that excessive or inappropriate speed is a major contributory factor in at least one-third of all road crashes, making it the single most important contributory factor to casualties on our roads\(^ {18}\). It is understandable that road safety professionals should make speed management a priority in casualty reduction strategies.

Studies based on the crash history of 300 sections of road, 2 million measurements of speed and the self reported crash history of 10,000 drivers conclusively demonstrated the correlation between speed and crash frequency\(^ {19}\). In a given situation, as speed increases, the risk that a crash will occur also increases (see Figure 1).

The findings reflect the importance of drivers having time to respond to the unexpected. At higher speeds there is less time to react appropriately.


\(^{15}\) Ibid.


\(^{17}\) Association of British Drivers’ website: http://www.abd.org.uk


Crash frequency is related to average speed, the spread of speeds and the percentage of drivers exceeding the speed limit. Simple physics dictate that injury severity increases with speed. Figure 2 shows that even slight decreases in speed are beneficial, especially for death and serious injury. Research by TRL has indicated that reducing the speeds of the fastest drivers would yield the greatest benefits in reducing death and injury on the roads. Some critics of speed cameras use TRL Report 323 to argue that speed is a contributor to only 7% of road crashes. However, TRL 323 was not a study of crash causation or of the role of speed in crashes, but rather an evaluation of a crash reporting methodology. The 7.3% figure in the report refers not to a proportion of crashes but rather a proportion of factors recorded by police and since on average two factors were recorded for each crash for which the methodology was used, it shows that excessive speed was recorded as a factor in at least 15% of crashes.

Marie Taylor, head of TRL’s programme of research on speed and accidents, has commented on the erroneous interpretation of TRL323. She points out that in addition to speed being recorded as a factor, it will have been ‘part of the reason for other factors being recorded’ such as failure to judge another’s path or speed. It will compound factors such as following too close and aggressive driving. Finally, she notes that excessive speed was recorded as a factor in more than a third of the fatal crashes recorded and that the contribution from other speed-related factors ‘will mean that the true effect of speed is likely to be even greater than this’.

3 RAISING SPEED LIMITS IN THE USA MADE NO DIFFERENCE TO CASUALTIES

Claim: In an article titled ‘Motorists cry foul at rise in speed cameras’, the Daily Telegraph argued that speed ‘does not of itself cause accidents’ and that ‘when the 50mph national speed limit was lifted in America, there was no noticeable increase in accidents caused by speed’.

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20 Ibid.
**Reality:** This would be very interesting if it were true. In 1987 the national speed limit in the United States rose from a 55 mph limit imposed during the fuel crisis in the early 70s to 65 mph. In 1995 individual states were allowed to set their own limits. A recent report found that the post-1995 rise in speed limits in many American states has triggered a 35% increase in death rates. The report compared 22 states that raised interstate highway speed limits to 70 or 75 mph when the federal speed limit was abolished in 1995 to 12 states where the limit stayed at 65 mph, and found that there were 1,880 more deaths on interstates between 1996 and 1999 in states with higher speed limits. The reverse effect is also evident: in 1974, when the national speed limit was lowered to 55 mph, fatality rates dropped by 50% on the interstate highways and by 70% on other four-lane rural highways. The US National Highway Traffic Safety Administration is now advocating the adoption of speed camera laws similar to those in the UK to help counteract the rising death toll.

4 **CAMERAS ARE NOT SITED ON THE MOST DANGEROUS ROADS**

**Claim:** Autocar Magazine in association with the RAC Foundation has claimed that speed cameras are not sited on the most dangerous roads and ‘the most lethal 10 roads in the country (as designated by Euro RAP) are covered by just four speed cameras’.

**Reality:** The European Road Assessment Programme (Euro RAP) is a system to compare the relative statistical risk of death and serious injury on European roads. An assessment of risk on Britain’s primary road network was published in September 2003. The data used to assess the roads, however, cover the period from 1997 to 2001 when only one of the police force areas covering the list of 10 most dangerous roads was involved in a pilot safety camera partnership. Until the netting off scheme was available, speed cameras were only infrequently used because of the costs involved in installing and servicing them. The Government has set stringent criteria for the siting of cameras by safety camera partnerships. These stipulate that for a new fixed camera to be installed there must have been at least four deaths or serious injuries on a given 1km stretch of road within the past three years. At least 20% of drivers must be exceeding the speed limit. Fixed cameras also require collisions to be clustered. Finally, camera policing of speed limits can only be introduced after all else has failed: ‘and there are no other obvious, practical measures to improve road safety along this stretch of road’. If rates of speeding on the roads identified by Euro RAP are not this high and there is evidence that the collisions are not speed-related, safety camera partnerships would be unable to install new cameras.

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5 CAMERAS DON’T CATCH THE MOST DANGEROUS DRIVERS

Claim: The RAC Foundation has claimed that speed cameras tend to catch the safest drivers, rather than the most dangerous. According to its research, the drivers most likely to be caught by speed cameras are middle-aged male company car drivers who cover large mileage, rather than young drivers, despite the fact that young drivers are involved in more crashes when licence holding is taken into account.

Reality: The profile identified by the RAC Foundation - company car drivers and drivers with high mileage - are not only more likely to have a speeding conviction; they are also more likely to be involved in crashes than other drivers. Reports have consistently found that company car drivers and high-mileage drivers who drive for work are 50% more likely to be involved in injury accidents than other drivers, even after differences in exposure due to miles driven have been taken into account. Pressure to speed has been identified as a contributing factor to this figure, alongside fatigue and in-car distractions.

Research also shows that ‘those drivers who had been stopped by the police for speeding or had been flashed by a speed camera had double the incidence of recent crash involvement’.

6 CAMERAS ARE NOT POPULAR

Claim: Opponents of speed cameras claim that they are ‘deeply unpopular’. The Daily Telegraph concluded from a recent opinion poll that ‘seven in 10 motorists think speed cameras are mainly revenue-raising devices that do little to reduce car accidents’.

Reality: Opinion polls generally indicate widespread public support for speed cameras, although some polls (like that cited in The Daily Telegraph) do not. A recent ‘poll of polls’ by Transport 2000 – based on six different surveys – shows that support for the use of speed cameras averages 74 per cent. Similarly, during trials of speed cameras, a DfT survey found that over 80 per cent of people living in pilot areas agreed that ‘cameras are meant to encourage drivers to keep to the speed limit, not to punish them’.

34 DfT. 2003a. op cit.
7 CAMERAS ARE A WASTE OF MONEY

Claim: Some critics of speed cameras argue that ‘cameras are a waste of money’.

Reality: Speed cameras are remarkably cost-effective. In the two-year pilot study of cameras in six counties, there were 280 fewer people killed or seriously injured at camera sites than would otherwise be expected. This means that the total cost saving of casualties at camera sites over two years was around £58m\(^{35}\). This figure is several times higher than both the amount spent on camera enforcement (£21 million) and the amount raised in fixed penalty income (£27 million)\(^{36}\). When the reduction in casualties across the pilot area (4% reduction in KSI) is taken into account, it is estimated that the total benefit to society over two years is approximately £112 million.

A previous Home Office Police Research Group cost benefit analysis of speed cameras found that cameras generate a return of five times the investment after one year and 25 times the amount after five years\(^{37}\).

8 CAMERAS RAISE REVENUE FOR POLICE AND LOCAL AUTHORITIES

Claim: A Daily Telegraph article on speed cameras claimed, ‘The cameras generate around £80 million a year in income … Much of this money is retained by the police, something that critics believe merely encourages the proliferation of the cameras’.

Reality: Neither the police nor local authorities retain income from speed cameras. As a DfT briefing on safety cameras explains:

\begin{quote}
Safety camera partnerships are not there to raise money and neither the police nor the local authority receive any money from the operation of safety cameras. Strict Treasury rules mean that any money from fines that is returned to the safety camera partnerships can only be spent on the operational costs of their camera network, including new cameras where the need can be identified. All remaining money goes to the Treasury; it does not stay with the Partnership\(^{38}\).
\end{quote}

\(^{35}\) This figure is calculated on the basis of lost output, medical and ambulance costs and human costs, based on DfT values for the prevention of road fatalities and serious injuries. DfT. 2003a. \textit{op cit}.

\(^{36}\) \textit{Ibid.} The monetary figures refer to amounts in the original 8 county pilot area, while the casualty figures refer to the 6 county areas. This indicates that the true cost-benefit ratio may be significantly more favourable.


Of the £27 million raised in fines during DfT’s two-year camera pilot project, £21 million went to the safety camera partnerships to cover the costs of camera enforcement; the remaining £6 million went to the treasury.\(^{39}\)

### 9 CAMERAS HAVE CONTRIBUTED TO A FALL IN TRAFFIC POLICING

**Claim:** An article in Autocar claims that speed cameras are a waste of police time and that policemen have been directed ‘by authorities to abandon their duties in favour of flash-equipped grey boxes’.\(^{40}\)

**Reality:** There has been a gradual decline in the number of designated traffic police officers from 15–20% of constable strength in 1966 to approximately 7% of force strength in 1998\(^{41}\), and this trend has continued recently\(^{42}\). This is a worry for everyone concerned about road safety. There is little evidence, however, to suggest that speed cameras are responsible for this decline. Instead of speed cameras occupying police time, a Home Office Police Research Group paper noted that ‘many forces had found that the use of camera technology released traffic officers for other duties’\(^{43}\). Fixed speed cameras reduce the speed limit enforcement burden on traffic officers while speed limit enforcement reduces the time spent in dealing with collisions and their aftermath. Traffic policing and camera enforcement are mutually reinforcing, not mutually exclusive.

In a thematic inspection of ‘Road Policing and Traffic’, Her Majesty’s Inspectorate of Constabulary concluded that the decline in the numbers of designated police officers is due to increasing demands on the police (particularly by more high-profile policing activity) and competing pressures on police time. The failure to sufficiently prioritise traffic policing is fuelled in part by policing indicators that largely exclude traffic enforcement and by a failure to include road traffic enforcement as a ‘key priority’ for policing. Of 31 indicators listed in the National Policing Plan 2004-2007, only one (a very general indicator of road casualties per vehicle kilometre) relates directly to traffic enforcement\(^{44}\). Road traffic enforcement is excluded from the list of ‘Key Priorities’ in the National Policing Plan, but appears instead under ‘Other Areas of Police Work’. PACTS and SSI believe that identifying road traffic enforcement and casualty reduction as a key policing priority would have a major effect in reversing the decline of traffic policing.

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10 THE NUMBER OF TRAFFIC OFFENCES DETECTED HAS FALLEN

Claim: Autocar Magazine in association with the RAC Foundation has claimed that speed cameras remove police from the roads, ‘so thousands of serious driving offences now go undetected’.

Reality: Recorded incidence of many serious driving offences have risen in recent years, in contrast to these claims. Contrary to the figure of ‘a fall of 50,000 in the number of dangerous driving offences detected’, the Home Office statistical report 'Crime in England and Wales 2002/3' indicates an increase of 65% (from 4,589 to 7,551) in the number of dangerous driving offences recorded between 1998/9 and 2002/3 (earlier data are not available)\(^45\). Contrary to claims that fraudsters are not being detected, the same report shows recorded vehicle/driver forgery incidents increased from 6,028 to 8,553 – an increase of 42% – over the same period.

While the number of recorded dangerous driving incidents has risen, the number of successful prosecutions for dangerous driving has fallen (3,898 findings of guilt in 2001 compared to 6,849 in 1993\(^46\)). This may be partially explained by an earlier reluctance to prosecute by the Crown Prosecution Service. This is an area of particular concern for road safety organisations and is developed further in PACTS’ Research Report Road Traffic Law and Enforcement: A driving force for casualty reduction\(^47\).

CONCLUSION

As this review of research evidence indicates, excessive and inappropriate speed is a major contributing factor to road crashes and casualties. A comprehensive approach to speed management remains central to the continuing drive to reduce death and injury on our roads. Speed cameras have proven to be an extremely successful element of an integrated speed management strategy, and studies have consistently shown that deaths and serious injuries have been reduced by over a third at speed camera sites. In this context, it is important to dispel some of the myths about cameras. Rather than ‘punishing motorists’, speed cameras may instead save the lives of motorists and other road users.

Parliamentary Advisory Council on Transport Safety www.pacts.org.uk; mail@pacts.org.uk
The Slower Speeds Initiative www.slower-speeds.org.uk; info@slower-speeds.org.uk

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Annex 2.

Detailed cost-benefit analysis of the Austrian Section Control at the Kaisermühlen tunnel

1 COSTS OF THE MEASURE

Investment costs for the Section Control in the Kaisermühlen Tunnel add up to €1,200,000 (2002 price). Construction work of gantries, cables and data lines to the Section Control server are included in this price. Annual costs of operation and maintenance (table A2.1) are about €60,000, covering a service contract of 4 service cycles per year plus additional repairs if the system starts malfunctioning. In order to not disrupt traffic flow, maintenance and repairs are done during night hours when traffic is usually very low.

According to the Austrian highway operator (ASFINAG), the Section Control system has a 10-year service life, beginning in 2003. After that period, software problems and missing spare parts for the hardware are expected to affect full operation of the system. Investment costs are incorporated in the form of an annual capital cost assuming a 4 percent interest rate in real terms. Total annual costs for operating the Section Control add up to €207,949 per year.

<table>
<thead>
<tr>
<th>Table A2.1. Total annual costs Kaisermühlen Tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Expenses factors</strong></td>
</tr>
<tr>
<td>Investment costs</td>
</tr>
<tr>
<td>Annual maintenance costs</td>
</tr>
</tbody>
</table>

1.1 Economic benefits due to reduced road traffic emissions

Road traffic is a major source of air pollution and emission of greenhouse gases in Austria. Although improvements in vehicle technology, the introduction of exhaust treatment systems (catalytic converters) and the development of higher quality fuels, have to some extent allowed emissions from vehicles to be significantly reduced, this effect has levelled off by a still ongoing increase in traffic performance. According to latest studies\(^{48}\), traffic volume in and around Vienna will rise by more than 90\% till 2035 due to a steady increase in resident population, decentralization and daily distances covered.

\(^{48}\) SAMMER et al, 2004, page 25
As stated in the previous chapter, a major effect of Section Control is harmonization of velocity, i.e. vehicle drivers maintain a constant speed, reducing “Stop-and-Go” traffic and congestion. The model\textsuperscript{49} used for computing the resulting changes in road traffic emissions was created by the Austrian Umweltbundesamt, the governmental authority for protection and control of the environment, in close cooperation with associated institutes in Germany and Switzerland. The “Handbook of Emission Factors for Road Transport” provides emission factors in g/km for all current vehicle types (passenger cars, Light Duty Vehicles, Heavy Goods Vehicles and motorcycles), each divided into different categories for a variety of traffic situations. The following parameters have been used to define the model:

- Type of emission: hot emissions, cold start emissions, evaporation
- Vehicle type: passenger car - Heavy Goods Vehicle (HGV)
- Estimated changes in composition of the vehicle fleet (2003-2013)
- Air pollutants (CO, NO\textsubscript{x}, SO\textsubscript{2}, PM\textsubscript{10}, VOC) and carbon dioxide (CO\textsubscript{2})
- Type of road: urban motorway
- Time of day: daytime/nighttime

\textit{Table A2.2} gives values for both air pollutants and CO\textsubscript{2} as the most important greenhouse gas emitted by road traffic. As can be seen from the annotations in the footer, different literature sources were used to obtain monetary estimations for the most important air pollutants emitted during combustion. To arrive at 2002 prices, German Mark (DM) and Norwegian Krona (NOK) were first converted into Austrian Shillings (ATS) and then brought to a 2002 price level by using official inflation rates (see appendix). Values of traffic emissions were finally converted to € by multiplication with 0.07267.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|l|l|}
\hline
Air pollution & Unit of valuation & Value per unit & \\
\hline
CO & Tons of NO\textsubscript{x}-Equivalent\textsuperscript{52} & 1700 DM (1995)\textsuperscript{50} & 974.64 NOK (1995)\textsuperscript{51} & € (2002) \\
NO\textsubscript{x} & kg of NO\textsubscript{x} & 115 & 14.90 \\
SO\textsubscript{2} & kg of SO\textsubscript{2} & 37 & 4.79 \\
Particle (PM\textsubscript{10}) & kg of PM\textsubscript{10} & 1800 & 233.27 \\
VOC & kg of VOC & 15 & 1.94 \\
CO\textsubscript{2} & Tons of CO\textsubscript{2} & 220 & 28.51 \\
\hline
\end{tabular}
\caption{Valuation of environmental impacts in cost-benefit analyses.}
\end{table}

For quite some years, considerable efforts have been made by the European Commission to reduce fuel consumption and, consequently, emissions of carbon dioxide. In 1992, the Auto-Oil I Program was introduced within the European Union to define emission ceilings (EURO

\begin{thebibliography}{99}
\bibitem{49} KELLER, HAUSBERGER, 2004
\bibitem{50} EWS, 1997, page 41
\bibitem{51} ELVIK, 1999, page 24
\bibitem{52} Conversion factor: 1 ton of CO = 0.003 tons of NO\textsubscript{x}-Equivalent (EWS, 1997, page 41)
\end{thebibliography}
classes) for passenger cars as well as Heavy Goods Vehicles and to set quality standards for fuels for 2000 and beyond.

One key measure in this respect was a voluntary agreement with car manufactures to reduce CO₂ emissions from new passenger cars to 140 g/km by the year 2008/2009. For the Kaisermühlen Tunnel, this boost in vehicle technology along with a lower average speed due to Section Control results in more than 12,000 tons of saved CO₂ emissions, having a discounted monetary value of more than € 280,000.

Table A2.3. Monetary value of saved emissions Section Control (2003-2013).

<table>
<thead>
<tr>
<th></th>
<th>Changes in road traffic emissions (t)</th>
<th>Discounted value of traffic emissions in € (2002-price)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>- 14.9</td>
<td>-137</td>
</tr>
<tr>
<td>NOₓ</td>
<td>- 39.0</td>
<td>-431,639</td>
</tr>
<tr>
<td>SO₂</td>
<td>- 0.4</td>
<td>-1,552</td>
</tr>
<tr>
<td>Particle (PM10)</td>
<td>- 0.5</td>
<td>-87,029</td>
</tr>
<tr>
<td>VOC</td>
<td>+ 7.3</td>
<td>+11,247</td>
</tr>
<tr>
<td>CO₂</td>
<td>- 12,879.6</td>
<td>-281,973</td>
</tr>
<tr>
<td>Accumulated value</td>
<td></td>
<td>-791.084</td>
</tr>
<tr>
<td>Monetary value of saved emissions per year</td>
<td></td>
<td>-79,108</td>
</tr>
</tbody>
</table>

Nitrogen oxide emissions are among the most harmful of all air pollutants. Thus, various nitrogen oxide catalytic converters have been developed which will help to reduce emissions of NOₓ significantly over the next 10 years. Expected changes can be seen in the following figure, which states above all a constant decrease in saved nitrogen oxide emissions because of improvements in vehicle technology. In the year 2003 nearly 6 tons of NOₓ were saved through Section Control (Table 11). This value decreases to one ton of NOₓ in 2013. Calculated over the economic lifetime of the Section Control system, savings in NOₓ emissions amount to a value of more than € 430,000.
Volatile organic compounds (VOC), in combination with nitrogen oxides, are responsible for ground level ozone and smog. VOC are primarily produced when fuels are incompletely combusted. Looking at the VOC traffic emissions in the period under observation, an increase of one ton in 2003 and slightly less in the following years has been calculated. This is due to the fact that most vehicle engines have their lowest VOC output between 80 and 100 km/h. A decrease in average speed to 75 km/h (passenger cars) or 55 km/h (HGV) amounts to an increase of VOC emissions (figure A2.1).

1.2 Effect on accidents

In its first 2 years of operation, a positive impact of Section Control concerning accidents in the Kaisermühlen Tunnel was observed. Apart from the reduction in total numbers of casualty accidents, the severity of injury was also positively affected. In a four year period prior to the start of the Section Control system (Ib–IVb), one fatal or severely injured (0.5 + 0.5) and 10 slightly injured were recorded on the average every year. Since August 2002 no fatality was observed in the Kaisermühlen Tunnel, while the number of slightly injured road users decreased to an average of 7 in the after-period.
Table A2.4. Injury accidents before and after Section Control implementation.

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Period</th>
<th>Injury accidents</th>
<th>Fatalities</th>
<th>Seriously injured</th>
<th>Slightly injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.08.1999</td>
<td>12.08.2000</td>
<td>IV&lt;sub&gt;b&lt;/sub&gt;</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>12.08.2000</td>
<td>12.08.2001</td>
<td>III&lt;sub&gt;b&lt;/sub&gt;</td>
<td>7</td>
<td>0</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>12.08.2001</td>
<td>12.08.2002</td>
<td>II&lt;sub&gt;b&lt;/sub&gt;</td>
<td>7</td>
<td>1</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>12.08.2002</td>
<td>12.08.2003</td>
<td>I&lt;sub&gt;b&lt;/sub&gt;</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td>12.08.2003</td>
<td>12.08.2004</td>
<td>I&lt;sub&gt;a&lt;/sub&gt;</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>12.08.2004</td>
<td>12.08.2005</td>
<td>II&lt;sub&gt;a&lt;/sub&gt;</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td><strong>Mean (IV&lt;sub&gt;b&lt;/sub&gt; – I&lt;sub&gt;b&lt;/sub&gt;)</strong></td>
<td></td>
<td></td>
<td><strong>7.0</strong></td>
<td><strong>0.5</strong></td>
<td><strong>0.5</strong></td>
<td><strong>9.8</strong></td>
</tr>
</tbody>
</table>

Accidents are statistically rare events. Part of the nature of such events is that the precise time and place of their occurrence, as well as the precise nature of their impacts, are hardly predictable, i.e. in some periods, the recorded number of accidents on given points of the road network are greater (or less) than the average values expected for those points. In the following figure, the grey dots represent the recorded number of accidents and slightly injured road users in the Kaisermühlen Tunnel (fatal and serious injuries were omitted due to small numbers). The white dots show the moving average of the annual counts. In the first year, this is the same as the number of accidents or slightly injured for that year. In the second year, it is the average of the first two years, in the third year, it is the average of the first three years, etc.

It can be seen that the recorded number of slightly injured road users (figure A2.2) in a given year is not necessarily representative of the mean annual number. The annual recorded number of slightly injured, for example, varies between 9 and 11. Thus, if a safety inspection leads to choosing these points for treatment, a selection bias occurs and, in the measurements made after the treatment, an effect of diminution is registered (regression to the mean), independent of the treatment. The average value of the four years prior to the installation of Section Control (I<sub>b</sub>-IV<sub>b</sub>) have been chosen for acting as the basis for a medium-long term trend.
To properly quantify the safety effect of Section Control, a simple before/after comparison of accidents is not suitable. It is necessary to compare the situation with Section Control (“after”) with the anticipated situation that would have occurred without Section Control. The latter presents a calculated value of a previously observed (“before”) situation. Therefore, various types of risk indicators (fatality rate, rate of severely injured road users, etc.) and their means and standard deviations were computed.

Traffic performance in the before-period (I\textsubscript{b}-IV\textsubscript{b}) increased in a linear way, while in the first of the two after-periods (I\textsubscript{a}) a slight drop in vehicle-km was observed (Table A2.5). In the following year (II\textsubscript{a}) traffic performance resumed its’ upward course. Because numbers of fatal and serious injuries are too low to produce meaningful results, these two categories were combined for further calculations. Furthermore, some effects of serious injuries on the quality of life (e.g. lifelong paraplegia) deem it necessary to ascribe these victims the same weight as fatalities.
Table A2.5. Traffic performance and accident rates (per million vehicle km) in the Kaisermühlen Tunnel.

<table>
<thead>
<tr>
<th>Period</th>
<th>Traffic performance [million vehicle-km]</th>
<th>Accident rate</th>
<th>Rate of fatal and serious injuries</th>
<th>Rate of slight injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVb</td>
<td>67.6</td>
<td>0.10</td>
<td>0.015</td>
<td>0.15</td>
</tr>
<tr>
<td>IIIb</td>
<td>70.3</td>
<td>0.10</td>
<td>0.014</td>
<td>0.13</td>
</tr>
<tr>
<td>IIb</td>
<td>72.2</td>
<td>0.10</td>
<td>0.028</td>
<td>0.15</td>
</tr>
<tr>
<td>Ib</td>
<td>74.8</td>
<td>0.09</td>
<td>0.000</td>
<td>0.12</td>
</tr>
<tr>
<td>Ia</td>
<td>74.5</td>
<td>0.07</td>
<td>0.000</td>
<td>0.09</td>
</tr>
<tr>
<td>IIa</td>
<td>75.2</td>
<td>0.07</td>
<td>0.013</td>
<td>0.09</td>
</tr>
<tr>
<td>Mean (IVb - Ib)</td>
<td></td>
<td>0.10</td>
<td>0.014</td>
<td>0.14</td>
</tr>
<tr>
<td>Standard deviation (IVb - Ib)</td>
<td>0.004</td>
<td>0.011</td>
<td>0.015</td>
<td></td>
</tr>
</tbody>
</table>

The expected number of accidents (fatal or seriously injured/slightly injured) without the treatment being implemented results from multiplying the average number of accidents (per million vehicle-km) in table A2.6 with mean traffic performance in the “after” period (average of Ib and IIa). The ratio of “after” and (corrected) “before” values constitutes the actual safety effect of the measure.

Table A2.6. Corrected before and after values of accident severity due to Section Control.

<table>
<thead>
<tr>
<th></th>
<th>Expected number (corrected before value)</th>
<th>After value</th>
<th>Ratio53</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury accidents</td>
<td>7</td>
<td>5</td>
<td>0.71</td>
</tr>
<tr>
<td>Fatal or seriously injured</td>
<td>1</td>
<td>0.5</td>
<td>0.50</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>10</td>
<td>7</td>
<td>0.70</td>
</tr>
</tbody>
</table>

The analysis also controls for general trends in the number of accidents by using the total number of accidents on motorways in the “before” and “after” period as a comparison group (table A2.7). The mean number of comparison group accidents in the before period was 2,485, respectively, and 2,530 in the “after” period. Thus, the number of comparison group accidents is sufficiently large to be only minimally influenced by random fluctuations. The effect of Section Control on the number of accidents (or fatalities or injured road users) was estimated as follows:

Safety effect [%] = 1 - \[\frac{X_a}{E(m)_{b}} / \frac{C_a}{C_b}\]

Where:
- \(X_a\) = recorded number of accidents in the “after” period
- \(E(m)_{b}\) = expected number of accidents (correct before value) in the “before” period
- \(C_a\) = number of comparison group accidents in the “after” period

53 Slightly different numbers due to round off errors in the computation of the ratio
\( C_b = \text{number of comparison group accidents in the “before” period} \)

**Table A2.7. Injury accidents and severity casualties on Austrian motorways in the before/after period.**

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Period</th>
<th>Injury accidents</th>
<th>Fatalities</th>
<th>Seriously injured</th>
<th>Slightly injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.08.1999</td>
<td>12.08.2000</td>
<td>IVb</td>
<td>2,535</td>
<td>134</td>
<td>1,218</td>
<td>2,847</td>
</tr>
<tr>
<td>12.08.2000</td>
<td>12.08.2001</td>
<td>IIIb</td>
<td>2,468</td>
<td>165</td>
<td>1,255</td>
<td>2,703</td>
</tr>
<tr>
<td>12.08.2001</td>
<td>12.08.2002</td>
<td>IIb</td>
<td>2,402</td>
<td>121</td>
<td>1,173</td>
<td>2,663</td>
</tr>
<tr>
<td>12.08.2002</td>
<td>12.08.2003</td>
<td>Iib</td>
<td>2,534</td>
<td>124</td>
<td>1,133</td>
<td>2,819</td>
</tr>
<tr>
<td>12.08.2003</td>
<td>12.08.2004</td>
<td>Ia</td>
<td>2,564</td>
<td>110</td>
<td>1,204</td>
<td>2,778</td>
</tr>
<tr>
<td>12.08.2004</td>
<td>12.08.2005</td>
<td>IIa</td>
<td>2,496</td>
<td>100</td>
<td>1,035</td>
<td>2,801</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean ((IV_b – I_b)) 2,485</td>
<td>136</td>
<td>1,195</td>
<td>2,758</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean ((I_a – II_a)) 2,530</td>
<td>105</td>
<td>1,120</td>
<td>2,790</td>
</tr>
</tbody>
</table>

Statistical inference draws conclusions about a population based on sample data. It also provides a statement, expressed in the language of probability, of how much confidence we can place in the conclusions. The different values for the safety effect of the following table act as estimators of the (unknown) population parameter:

**Table A2.8. Safety effect of Section Control on accident severity.**

<table>
<thead>
<tr>
<th></th>
<th>Odds ratio</th>
<th>Safety effect [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury accidents</td>
<td>0.67</td>
<td>-33.3</td>
</tr>
<tr>
<td>Fatal and serious injuries</td>
<td>0.51</td>
<td>-48.8</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>0.68</td>
<td>-32.2</td>
</tr>
</tbody>
</table>

**Table A2.9. Valuation of savings in nr of accidents and injury severity due to Section Control.**

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount of savings</th>
<th>€ per unit (2002-price)</th>
<th>Cumulated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatalities</td>
<td>1</td>
<td>949,897</td>
<td>949,897</td>
</tr>
<tr>
<td>Seriously injured</td>
<td>1</td>
<td>51,439</td>
<td>51,439</td>
</tr>
<tr>
<td>Slightly injured</td>
<td>3</td>
<td>4,359</td>
<td>13,077</td>
</tr>
<tr>
<td>Property damage</td>
<td>2</td>
<td>5,745</td>
<td>11,490</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1,025,903</td>
</tr>
</tbody>
</table>

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54 BUNDESMINISTERIUM FÜR WISSENSCHAFT UND VERKEHR, 1997, page 136-141
1.3 Revenues due to speed violation

In the period under observation (13.09.2003–27.08.2004), more than 29 million vehicles passed through the Kaisermühlen Tunnel and about 40,000 drivers were charged because of excessive speeding (table A2.10). The top speed of a vehicle heading north was 175 km/h and 154 km/h heading south. About 5% (2,161) of all fines issued were acquired by HGVs. Keeping in mind that more than 10% of daily traffic is due to HGVs, a possible explanation for this phenomenon can be found in the high proportion of foreign vehicles among lorries. Due to the fact that mutual recognition of financial penalties has only been established with Germany and Switzerland, most of the foreign speed violators cannot be prosecuted.

<table>
<thead>
<tr>
<th>Heading</th>
<th>Vehicles passing the Section Control</th>
<th>Fines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heading south (A23)</td>
<td>13,450,345</td>
<td>19,162</td>
</tr>
<tr>
<td>Heading north (Stockerau)</td>
<td>15,973,473</td>
<td>19,558</td>
</tr>
<tr>
<td>Total</td>
<td>29,423,818</td>
<td>38,720</td>
</tr>
</tbody>
</table>

At the Tampere European Council (15 and 16 October 1999), the Heads of State or Government of the EU-Member States and the President of the Commission agreed that mutual recognition of criminal and financial matters should be a cornerstone of judicial cooperation within the European Union. Thus, France, the United Kingdom and Sweden initiated the adoption of a Council Framework Decision which enables Member States to execute criminal and financial offences against citizens of other Member States. Although this proposal is far from reaching legal status due to objections from several countries, it can be expected to pass legislation within the next 3–5 years. Obtaining fines from foreign speed violators should then be possible and benefits will be maximized.

According to Austrian law 80% of the fines from speed violations belong to the operator of the infrastructure, which (in case of the Section Control) is the Austrian highway operator (ASFINAG). The remaining 20% are used to cover the maintenance costs of the system settled by the Federal Ministry of the Interior.

Table A2.11 tails fines for different levels of speeding. Drivers exceeding the speed limit by more than 50 km/h have their driving licences revoked. During the observation period, this happened in 46 cases.
Table A2.11. Revenues due to excessive speeding in the Kaisermühlen Tunnel.

<table>
<thead>
<tr>
<th>Speed Violation</th>
<th>Fine</th>
<th>Violators</th>
<th>Revenues due to speed violation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 9 km/h</td>
<td>€ 21</td>
<td>16,176</td>
<td>339,696</td>
</tr>
<tr>
<td>10 – 19 km/h</td>
<td>€ 42</td>
<td>22,048</td>
<td>926,016</td>
</tr>
<tr>
<td>20 – 29 km/h</td>
<td>€ 56</td>
<td>2083</td>
<td>116,648</td>
</tr>
<tr>
<td>30 – 39 km/h</td>
<td>€ 70</td>
<td>409</td>
<td>28,630</td>
</tr>
<tr>
<td>40 – 50 km/h</td>
<td>€ 140</td>
<td>119</td>
<td>16,660</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>40,881</td>
<td>1,427,650</td>
</tr>
</tbody>
</table>

1.4 Computation of the Cost-Benefit Ratio

The Cost-Benefit Analysis is based on the principle of economic efficiency, i.e. to estimate if a measure is worth being implemented, the benefits and costs of the treatment are computed and brought into relationship. The benefit term includes all positive (monetary) effects of the measure. In the case of Section Control, benefits consist of reductions in accidents and road traffic emissions. Revenues from speed violators were omitted in the calculation of the Cost-Benefit Ratio because of the fact that in an economic point of view, it is irrelevant if the money belongs to consumers buying goods and therefore increasing their personal benefits or the highway operator which uses the fines for additional safety campaigns. The Cost-Benefit Ratio will be the same at both events.

Different benefits are added to obtain a total benefit. The cost term on the other hand denotes implementation and maintenance costs.

The Cost/Benefit-Ratio (CBR) is defined as:

\[
\text{CBR} = \frac{\text{Present value of all benefits}}{\text{Present value of implementation costs}}
\]

Combining the benefits and costs calculated in the previous chapters, a net present value of all benefits (without fines from speeders) of €1,105,001 and costs of €207,949 is obtained (table A2.12). Both values amount to a Cost/Benefit-Ratio of 5.3. Analysis of safety measures in Work Package 1 of ROSEBUD\textsuperscript{55} considers measures with a CBR larger than 3 as “excellent”.

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\textsuperscript{55} Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-making. ROSEBUD is a thematic network funded by the European Commission to support users of efficiency assessment tools at all levels of government.
Table A2.12. Present value of costs and benefits in € due to Section Control (2002 price level).

<table>
<thead>
<tr>
<th>Components of the CBA</th>
<th>Benefits</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road traffic emissions</td>
<td>79,108</td>
<td></td>
</tr>
<tr>
<td>Accident costs</td>
<td>1,025,903</td>
<td></td>
</tr>
<tr>
<td>Installation and maintenance costs</td>
<td></td>
<td>207,949</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1,105,011</td>
<td>207,949</td>
</tr>
</tbody>
</table>
Annex 3.

ISA trial in Sweden: Background

During the period 1999-2002 the Swedish National Road Administration conducted a large-scale trial involving Intelligent Speed Adaptation in urban areas. Several thousand vehicles have been equipped with voluntary, supportive (active), and informative systems to help keep drivers from exceeding the speed limit.

Over the three years of the project, the Swedish National Road Administration provided SEK 75 million in funding, and was also responsible for the overall co-ordination of the technology involved, as well as for evaluating the comparative advantages and disadvantages of the various systems.

The aim of the trial, which was conducted jointly with four Swedish municipalities, was to learn more about:

- Driver attitudes and usage
- Impact on road safety and the environment
- Integration of the systems in vehicles
- Prerequisites for road informatics on a large-scale.

ISA is primarily an application for towns, as well as residential areas and other sensitive environments where speed bumps are commonly used. Naturally it should also be possible to use the speed adaptation system for roads other than 30 and 50 km/hour roads, but in the trial, interest was focused on urban areas, where no spontaneous development is currently in progress via vehicle development.

1999 saw the planning of how the trial would be implemented and evaluated and in 2000 the systems started being installed in the vehicles. Most of the actual field trials were carried out in 2001, when at most some 5000 vehicles were on the roads; these were driven by more than 10000 drivers. This resulted in the ISA trial becoming the largest in world so far. Consequently, many persons can testify how it is to drive with ISA. Numerous measurements and interviews have been made during the trial period. All the data from the trial was compiled and analysed during 2002. At the same time numerous experiences for discussion of the continued introduction have been collected.

The submitted report documented the background, implementation, and the results of the comparative evaluation of the individual systems, which were made centrally by the Swedish National Road Administration. The report was designed to provide information and guidance for the continued consideration of a possible introduction of a speed adaptation system on a large-scale.
1.5 Technology description.

The basic functions of any ISA system are:

- Determining the applicable maximum speed limit (location and time dependent)
- Determining the actual speed of the vehicle
- Support the driver in speed adaptation.

Different technical solutions were tried to accomplish all three functions.

**Determination of the applicable maximum speed limit**

In order for the ISA system to be able to calculate the appropriate highest speed (the legal speed limit) it must know the time and position of the vehicle and what speed limits apply at different locations and possibly times. This requires:

- A “positioning system” that tracks the position of the vehicle
- A map (database) with the legal speed limits
- Software that matches the positions on the map and finds the legal speed limit at the location and time in question.

These tasks can be carried out in several different ways, which gives some principal technical guidance in the creation of an ISA system.

**Choice of the positioning system**

The positioning system normally consists of components in the vehicles that receive signals which are transmitted from a reference transmitter and calculates the position of the vehicle relative to these. In addition, the position must be supplemented with information from sensors that measure the speed, direction, etc. of the vehicle. Two main paths can be followed:

- Construct your own network of reference transmitters in the area in question

To construct your own network of reference transmitters can be done, for example, by using microwave technology (transponder technology). This technology was used in the trial in Umeå where 200 transmitters were installed.

To build up an infrastructure like this will be very expensive, which is why this technology will be more suitable when a large number of vehicles are to be positioned within a limited area, which was the case in the Umeå trial where 4000 vehicles participated.

The advantages of this technology are to have a good and stable precision in positioning, independent of other systems and cheaper vehicle equipment.

The expensive investment in infrastructure and road installations can be avoided by using an existing positioning system instead, or to wait for the soon to be launched Galileo positioning system.

- Use an existing positioning system (GPS or upcoming Galileo, for example)
GPS (Global Position System) gives a precision of approximately 10 metres in positioning and can also measure speed. The primary disadvantage is that the positioning system only works when the vehicle equipment has free visibility towards at least 3 satellites, which limits the coverage and precision in urban areas, tunnels, etc.

However, it is possible to minimise this problem through supplementing the vehicle equipment with sensors that measure speed and direction. In addition to this even map-matching is usually used, which, among others, “snaps” the position to the closest road.

However, with these supplements the actual vehicle computer becomes more expensive than corresponding transponder technology.

GPS was considered to be the available positioning system that best suited the objective of the project in Borlänge, Umeå and Lund.

Conveying the map (database) with speed limits to the vehicle

The problem in communicating a map with the legal speed limits to the vehicle includes:

- The speed map is located centrally and must be conveyed to all vehicles
- Speed limits change, which means the speed map needs to be updated in all vehicles continuously
- The speed map can be too large for the small vehicle computers
- The speed map can be too large to transfer using ”ordinary telecommunications”.

As the primary objective of the ISA trial was to evaluate the effect on road safety and the attitudes of the drivers, and not to solve problems concerning the technical infrastructure, these problems were avoided by defining sufficient small trial areas that the map could be stored on the vehicle computers.

With the transponder technology used in Umeå, each transmitter transferred a very local map that included legal speed limits up until the next transmitter. This system permitted changes to the speed limits as long as the road system did not change. In Lund and Lidköping the entire map was installed into the vehicle computer memory. Updates could only be applied by visiting the depot. In Borlänge the possibility of transferring and updating maps via GSM existed.

Determination of the actual speed of the vehicle

Two main methods could be chosen:

- Use the vehicle's existing system

In the Umeå system the vehicle's existing system for measuring speed was used, by connecting into a pulse encoder, which on most vehicles is the input data to the speedometer and kilometre counter. Calibration was necessary during installation in order to give good accuracy.
This measurement method reacted quickly to changes in speed and gave consistent speed data, but also consistent measurement error if the system was incorrectly calibrated, for example, after changing to other tyres.

One practical problem was that older vehicles did not have an electronic pulse encoder and that speed pulses on newer vehicles were only accessible via the vehicle's CAN bus, which in some cases was encrypted. This problem was sidestepped in the Umeå trial by eliminating such vehicles during recruitment.

In the GPS based system in Borlänge only speed data from the vehicle's GPS was used. This measurement method gave a slightly delayed effect and no or inferior speed data with bad satellite coverage. On the other hand, the occurrence of measurement errors was equally spread upwards and downwards around the correct speed and in doing so gave a very good average value. Measuring the driving speed with GPS required no connection to the vehicle (besides the power supply) or adaptation to different vehicle models.

In the GPS based systems, which were based on navigators and which were used in Borlänge, Lidköping and Lund, both the speed pulse and speed data from GPS were used. This allowed extremely accurate speed measurement. In most cases the ISA system gave a better speed measurement than that presented on many of the vehicles' speedometers.

**Supporting the driver in speed adaptation**

Finally, the different driver support solutions tested were the following:

- **Warning ISA:** The driver receives a warning signal (audio + visual) when the speed limit is exceeded.

- **Informative ISA:** In addition to the warning signals, the driver also receives information about the speed limit applying in the road in question.

- **Active gas ISA:** In addition to speed limit information, counter pressure is applied to the accelerator of the car when the driver exceeds the speed limit.

### 1.6 Results

The main results of the trial are briefly presented below.

In general it can be said that the expected positive effects were confirmed and even reinforced, while the results are mixed with regard to the non-effects or negative effects. For example, the drivers felt that they had become better drivers when using ISA at the same time, as there is a tendency to become either more active or passive with ISA in the vehicle.

**Improved road safety without increasing travelling time**

All in all the evaluation shows that it is reasonable to believe that road safety has improved significantly by using ISA. If everyone had ISA, there could be 20% fewer road injuries in urban areas.
The average speed on stretches of road has clearly fallen with ISA. The ISA vehicles drive more homogeneously and with less spread of speed, which probably increases safety even more. Pedestrian awareness has increased in the wake of this too.

Entry speeds into intersections (at the beginning of the braking process) have also fallen with ISA, more than half the effect towards the centre of the stretch. Even the lowest speed in the middle of the intersection has fallen for three-legged intersections (not four-legged intersections and roundabouts).

Travelling times in urban areas remain unchanged despite lower driving speeds in specific areas. The explanation is because there is less stopping and fewer braking situations with ISA. In this ways delays in queue situations and at intersections are reduced, and in doing so the average travelling time is not affected. Road-users experience travelling times as unchanged or marginally longer. Measurements for active gas indicate that travelling times are even marginally shorter.

**Acceptance of ISA is high**

A clear majority of drivers believed that you should keep to the speed limit on 30 and 50 km/hour roads.

Acceptance of ISA in urban areas is extremely high. Even higher than the level for seat belts before legislation was introduced. Around 35% used seat belts before it became statutory. When legislation was introduced usage increased to about 80%.

There is a belief of becoming a better driver when using ISA. Around two in three wanted to keep the system if it was free, while around one in three could even consider paying a limited amount. One in ten in Lund used the system voluntarily outside of the test area. (The speed limit was then set manually.)

**Test drivers sufficiently representative**

The recruitment group represented quite well the average driver. Those who chose to take part were somewhat more positive to the trial then those who chose not to take part, which is quite natural. Support of ISA was particularly appreciated on 30 and 50 roads and in vulnerable/dangerous road environments. In Umeå the fleet of vehicles represented – 4000 vehicles – as much as 10% of vehicle kilometres travelled which means the result ought to be sufficiently representative in order to draw sustainable conclusions. It was primarily due to technical reasons that persons could not take part in the trial. Women are however underrepresented among the test drivers, as they generally drive older models than men.

The test drivers thought it was easier to keep the speed limit when using ISA. It was an advantage to see the speed limit on a display. 70–80% considered the basic concept of ISA to be good, even if the technology (GPS-coverage, movement of the active accelerator) has not been completely reliable during the trials.

Problems and difficulties have interfered with the trials, yet in the evaluation the drivers, to a certain degree, have been able to distinguish between the equipment in the trials and the
technology itself. In all probability the opinions would have been even better without the problems, especially for active gas. Active gas caused the most trouble (sometimes, frequently or very often 37% in Lund, 46% Lidköping) followed by informative (41% in Borlänge, 14% in Lidköping) and warning (5% in Umeå).

**ISA-vehicles influence other road users**

The result in Umeå indicates that other road users were also affected by ISA. This means that large effects can also be attained even with a smaller amount of ISA vehicles on the road.

ISA may prove to be the best idea yet together with policing to solve road safety problems on 50 roads in urban areas. This is where most personal injuries occur and acceptance for alternative physical measures, for example, road bumps is low.

**Small differences between systems**

Effects on speed differed very little between the systems. The driving speed fell on stretches by up to 3-4 km/hour for each of the systems. The difference between the systems for the entire road system at 30-50 km/hour, which is the main focus of the trial, only amounted however to 0.3-0.4 km/hour. The reason being, among others that the audio signal in the warning system was experienced as so irritating that attempts were made to avoid it. In general this resulted in the same speed reduction as for active accelerator. Consequently, the choice of system should also be based on other criteria, such as cost, operating reliability, and user points of view.

Warning and informative systems were preferred in advance by most people among the general public and among those recruited. Only around half as many considered active gas to seem suitable. A distinctive trait after the trial was that the test drivers thought that the system they tested was the most effective in order to increase road safety.

Order of preference straight off for all test drivers is warning, informative, active gas; nevertheless, the differences are small! The parallel driving simulator study showed that the drivers had fixed perceptions about which system was preferable. Therefore it may be advisable to develop a system where the user can select between an active or passive system.

Drivers had to accelerate a little more with warning/informative and somewhat less with active gas. Drivers intended to look more at the speedometer with warning and a little less with active gas.

Attention to speed signs increased a little for warning, which has no display. It was unchanged for informative and it fell slightly for active gas.

Fuel consumption was believed to have dropped a little for informative, but only marginally for warning and active gas. According to the test drivers' own assessments, speed fell in the trial areas: on all stretches (30, 50, 70 km/hour). The experienced reduction was greatest for active gas, approximately 2 km/hour, the least for warning (10-20% lower).

Measurements supported the experience that the driving speed fell by 1-2 km/hour, while travelling times including stops remained unchanged.
The system has to be improved to become more attractive

ISA was perceived to be effective for the purpose, but the equipment was not so pleasing with regard to its design, etc. The possibility for the user to adjust the audio signal was one wish. Fewer than 20% have often or quite often wanted to switch off the audio.

Driving pleasure is unchanged for warning and informative systems, but fell a little for active gas.

Drivers noticed that the warning was given a few km/hour over the speed limit on their own speedometers. Greater demands should be made on speedometers in cars showing the correct speed when using ISA (or that ISA replaces the speedometer).

Subsidies or other incentives (lower insurance premiums, etc) may be necessary to stimulate voluntary acquisition.

Issues concerning the introduction of ISA

When you are the only one using ISA you feel more in the way. According to the drivers it was therefore important in the long term that ISA is going to be introduced for everyone.

Many believed that the introduction of ISA should be statutory for special groups (new driving licence holders, notorious speeding offenders and drink-drivers).

The state and municipalities can take the lead by equipping their own fleets of vehicles and through making demands on ISA for publicly procured transport services.

Commercial and company car drivers were generally negative to the trial and the introduction of ISA. Equipment has been sabotaged during the trial. The negative attitude of commercial drivers must be influenced through dialogue with the drivers as well as employers and by looking over stressful working conditions.

1.7 Introduction of ISA to the market

The results clearly indicated that ISA made a positive contribution towards road safety. They confirm previous experiences from smaller trials in Eslöv and Umeå regarding user acceptance and effects on the traffic. Feared negative effects have been exaggerated, but ergonomics need to be improved.

The speed measurements in Umeå and results from vehicle logs in Lund and Borlänge show undoubtedly that the average speed fell for vehicles equipped with ISA. Furthermore, the spread of speed was less. The higher the average speed the greater the reduction in speed provided that the prior average speed is over or close to the speed limit in question. The only sure difference between the systems is that the effect on the spread of speed is less for informative and warning systems than for active gas. The reductions in average speed are of the same magnitude.

ISA's design and function has caused problems, but one trusts the system. The greatest problems have been with active gas, which in the tested version, among others, affected the
driving characteristics of some vehicles when accelerating. This has probably affected the drivers in their evaluation of the technology and function. These deficiencies must be corrected before an introduction. Many have complained about the audio signal on warning respective informative ISA and this has been accentuated during the trial period. A softer tone was requested. Even the visual signal has caused some problems and many found it difficult to see the speed reading on the display when the sun was on it.

One idea with ISA is that the driver is warned when the speed limit is reached and thereby does not need to look at the speedometer or speed signs as much as without ISA. For active gas 40% of drivers said that they looked less at the speedometer and signs. For informative ISA there is no great difference while drivers with warning ISA looked a little more than usual. About half of the drivers with warning ISA increased their attention to both the speedometer and speed signs. As the warning system has no display this is a reasonable reaction.

More drivers with warning and informative systems considered that they needed to apply accelerator and brake more than earlier while it was the opposite for active gas drivers. A probable explanation is that the function in active gas automatically adjusts the speed once the speed limit is reached while drivers with informative and warning ISA must carry out an active action (lift off the accelerator and possibly brake).

The results also show that with active gas you attempt to reach the maximum permitted speed where possible. In other words, acceleration is always a little stronger when you accelerate than without ISA. This probably also applies for informative and warning systems too. Even if a specific increase can be noted for some factors with regard to mental strain it does not seem to have a negative effect on driving to any appreciable extent.

This is supported by there being a clear opinion that ISA does not demand attention from other, more important things while driving.

The trials show that the test drivers are predominantly positive to the system despite the technical and functional deficiencies that the systems have been marred by. If ISA should make a wide scale break through it is still important that the equipment has been ergonomically tested, works without problems, and is reliable. As the will to pay is low it is also important that the spread with a voluntary introduction is stimulated by subsidies or other incentives.

You can interpret the results that active gas has somewhat greater effects on exceeding the speed limit and in doing so safety. However, acceptance is greater for the warning and informative systems. Functional difficulties have certainly contributed towards this more than the effect on the speed for active gas.

In order to gain high acceptance in an introductory phase it is important to offer the possibility for the driver to choose between different functional models. Preferably these should be combined in an integrated system. It seems to be initially easier to accept the warning and informative systems. Eventually many feel that the audio signal is annoying and wish to replace it with a more unobtrusive warning. Active gas or another similar system may then be preferable.
**Introduction from a technical perspective**

If there is a will to introduce ISA on a large-scale, the technology exists. Distinct boundaries ought to be drawn between the role of the authorities and industry. The authorities ought to answer for providing a comprehensive and updated road database with speed limits and let industry produce the requisite vehicle equipment.

The difficulties of communicating legal speed limits to large fleets of vehicles should not be underestimated, especially if this speed information in the future should be dynamically adapted to current circumstances and be legally valid. The choice of what level of speed support can be considered suitable is not limited by the available technology.

Everything from discrete informative systems to more actively supportive or vehicle affecting are already fully feasible.

**Introduction from an automotive industry perspective**

In order for an ISA system to be sufficiently attractive, have a high acceptance level and high observance, dynamic speed limits should be introduced. Dynamic speeds increase the drivers' understanding for speed limits and also make it more meaningful to have support in the vehicle to help observe the speed limits.

The market can be aided by support such as tax relief or lower insurance premiums.

This will probably be necessary for, e.g. a GPS based ISA system to be possible around 2008 at a reasonable price for the user. It should also be reasonable as the benefit for society with this kind of system will initially be greater than for the individual.

System harmonisation, at least within Europe, is necessary in order to get the automotive industry involved in the technical development and hold down costs for the system.

**Introduction from a community perspective**

Against the background of the ISA trial results society ought to support the introduction of voluntary, supportive and informative ISA systems on a large-scale. Speed adaptation systems are expected to contribute towards increased road safety and a reduced number of fatalities and injuries on our roads.

In order to support and facilitate the introduction of ISA during the period 2002-2008 society ought to take the following steps:

- The Swedish National Road Administration provides all interested parties with information and knowledge from the implemented ISA trial. This includes recommendations about project planning, information and marketing (support), costs, technical equipment, operation and maintenance, etc.

- The Swedish National Road Administration speeds up via regional NVDB2-coordinate the development of NVDB in the geographical areas where speed adaptation systems are requested.
The Swedish National Road Administration co-ordinates with procurement applications for ISA systems to simplify the co-ordination of orders. Prices can be reduced with larger orders.

Orders can also be divided among different suppliers as it is of interest to both the Swedish National Road Administration and the automotive industry and its customers to have several manufacturers on the market. Procurement material/technical specifications of requirements are to be provided by the Swedish National Road Administration.

The Swedish National Road Administration furnishes recommendations for how many installations of speed adaptation systems ought to be made based on experiences from the ISA trial. Recommendations are to be drawn up in co-operation with the vehicle department and the contracted installation engineers within the ISA project.

The Swedish National Road Administration fits its internal fleet of vehicles with a speed adaptation system.

With the procurement of transport services for the Swedish National Road Administration speed adaptation systems should be requested. The Swedish National Road Administration also acts so that other parties follow suit.

The Swedish National Road Administration, together with the Swedish Ministry for Industry, Employment and Communications, investigates the possibilities of government subsidies for vehicles equipped with speed adaptation systems.

1.8 Recommendations guided by the Swedish ISA project

Guided by experiences from the Swedish ISA project - implementation, evaluation, technology, information and participation from the automotive industry the following recommendations can be given ahead of continued discussions about the introduction on the market. It should be born in mind that this was in 2002. It would be worthwhile to observe and analyse within the PEPPER project to what extend these recommendations have been realised and what conditions for success or failure emerged.

The project results are clearly positive from a road safety point of view and do not seem to have any significant negative side effects. We therefore strongly recommend society and the automotive industry in collaboration to work for the quickest possible introduction.

A majority of test drivers consider that an ISA system should be standard in future vehicles. The Swedish National Road Administration should immediately initiate that regulations (statutory or voluntary agreement with the automotive industry) are drawn up about the ISA system being a standard feature in future vehicles. The regulations should be completed by 2005 at the latest. In negotiations with the automotive industry a decision should be made regarding a fixed year from when the regulations
should start to apply; this should give the automotive industry reasonable time to
develop and install the ISA system as standard (for example, some time between
2008-2010).

Companies that can demonstrate a serious interest in developing and offering an ISA
system on the aftermarket ought to be given support from the government through
VINNOVA, etc in order to stimulate the emergence of well developed technologies
for after-sales installation of systems during the period 2003-2015.

Possibilities ought to be created to install ISA nationally or within limited areas for
fleets of vehicles through a reliable and continuously updated speed database being in
existence by 2005 at the latest.

The Swedish National Road Administration should take the lead by installing ISA in
its own fleet of vehicles by 2005 at the latest. Government and municipal authorities
ought to be encouraged to install ISA in their own fleets. Demands on the presence of
speed adaptation systems ought to be made with the procurement of public transport
services by 2008 at the latest.

Subsidies or other incentives ought to be introduced during the period 2003-2010 to
stimulate the use of ISA on the private market too. A study of the effects of different
incentives should be started immediately.

Sweden ought to act for an international introduction of speed adaptation systems
primarily within the EU. This should take place through the distribution of knowledge
about the ISA system’s effects and acceptance as well as to strive for international
agreement on HMI, standards, etc. Demands should also be made on improved
accuracy of speedometers in vehicles.

The speed limitation system and supervision policy should be reviewed in parallel
with regard to the new conditions that road informatics give.

Questions about the technology to keep the legal speed limits and which limits are
applicable should, if possible, be kept apart.

1.9 A possible introductory scenario

Guided by the recommendations the following introductory process is conceivable.

It would be worthwhile to observe and analyse within the PEPPER project to what extend these
recommendations have been realised and what conditions for success or failure emerged for the
period 2002 - 2006.

2002 – 2004

Negotiations in progress between the government and industry about regulations for
ISA in new vehicles.

Government subsidies introduced for those installing ISA voluntarily.
The Swedish National Road Administration starts the installation of ISA in all its own vehicles and demands this in association with the procurement of transport services.

VINNOVA, etc, financiers support companies that develop and sell ISA systems on the aftermarket.

Work to enter speed limits in the national road database to be intensified.

Introduction of dynamic speed limits.

Increased co-operation between the authorities and the automotive industry in Europe.

**2005 – 2009**

In 2005 the government presents new regulations for ISA as standard in new vehicles

Function and reliability for after sales installed systems has improved due to government support.

Earlier during the period, ISA has been installed in 5% of older vehicles with the help of the actions of the Swedish National Road Administration and other authorities in connection with the procurement of transport services.

Penetration has increased by up to 35% as private persons more and more request ISA by the end of the period.

Standardisation is in progress within the automotive industry so that ISA will work throughout Europe.

**2010 – 2014**

Co-operation between the government and the automotive industry has resulted in 2010 becoming the date that ISA becomes compulsory as standard in all new vehicles.

ISA has been installed in 60% of all vehicles.

Increased demand and greater manufacturing batches result in so low costs that ISA no longer needs government subsidies.

ISA is a matter of course and an opinion has been created, on a voluntary basis, for regulations about compulsory usage.

**2015 – 2019**

More than 80% of all vehicles have ISA systems and as early as 2015 a decision is made, completely undramatically, that the use of ISA becomes compulsory in Sweden. Several countries within the EU simultaneously make the same decision.

The availability of a well updated road database in Sweden and in larger parts of Europe has resulted in a large number of telematics services such as traffic
information, navigation, and a number of "mayday" functions etc., being connected with the ISA-system.

**2020 – 2024**

- Expansion of the mobile data communications has come so far that in principle 100% of the European road network is covered.

- In Sweden and most parts of Europe the Road Administrations have established traffic information centres (TIC) that have the task of continuously updating all vehicles on the road with essential guidance, traffic information and any restrictions.

**2025 – 2030**

- All vehicles according to law must be connected to a TIC.

- At the end of the period the Swedish National Road Administration and other Road Administrations successively dismantle all road signs as all essential information is displayed to the driver by means of the vehicle used for the journey or for the transport services.
Annex 4.

Speed Alert related information

Table A4.1. SpeedAlert speed limit categories and definitions

<table>
<thead>
<tr>
<th>Speed limit category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>General (implicit) speed limits</td>
<td>Speed limits in accordance with national speed legislation.</td>
</tr>
<tr>
<td>G.1 – Infrastructure</td>
<td>Speed limits depending on road category (motorway, other road, built up area...).</td>
</tr>
<tr>
<td>G.2 – Environment/weather</td>
<td>Speed limits that are subject to prevailing environmental or weather conditions. E.g. Rain and snow speed limits in France, and dependent on visibility in Germany. Day and night dependent speed limits would also fall under this category.</td>
</tr>
<tr>
<td>G.3 – Vehicle</td>
<td>Vehicle (and equipment) dependent speed limits. E.g., trucks, buses, and use of studded winter-tires.</td>
</tr>
<tr>
<td>G.4 – Driver</td>
<td>Driver dependent speed limits. E.g. young drivers</td>
</tr>
<tr>
<td>Specific (explicit) speed limits</td>
<td>Speed limits in accordance with speed legislation by governmental agencies, regional authorities and / or municipalities. These speed limits differ from general rules. They are site dependent and posted by fixed or variable road signs.</td>
</tr>
<tr>
<td>S.1 – Fixed speed limit, signposted</td>
<td>Speed limits, permanently posted by means of static road signs. Typical applications are specific speed limits for tunnels, dangerous curves, bridges, and built-up areas.</td>
</tr>
<tr>
<td>S.2 – Variable speed limit, fixed signposted.</td>
<td>Speed limits, fixed signposted indicating a variable speed limit. A typical application is a specific speed limit regulation during school hours. Outside the school hours, the default speed limit for the area will apply. The enacted regulation behind a variable speed limit (S2 and S3) is in each case not limited in duration and consequently states no date or time when it expires.</td>
</tr>
<tr>
<td>S.3 – Variable speed limit, variable message sign.</td>
<td>Speed limits, posted on variable message (road) signs (VMS), which may be of a permanent or mobile nature. A typical application is speed limits displayed by VMS over motorways to control traffic flow in the case of, for example, bad weather conditions or risk for traffic congestion. Depending in this case on the traffic or weather conditions the displayed speed limits will be variable. The enacted regulation behind a variable speed limit (S2 and S3) is in each case not limited in duration and consequently states no date when it expires.</td>
</tr>
<tr>
<td>S.4 – Temporary speed limit, fixed signposted.</td>
<td>Speed limits, fixed signposted indicating a speed limit restricted to a defined time period. These speed limits can vary depending on the regulation. The enacted regulation behind a temporary speed limit (S4 and S5) is in each case limited in duration and consequently states the date and time when it expires. A typical application is speed limit restrictions during a roadwork, which is predefined to a specific period. Another typical case is during police traffic control or accidents when police or other authorised actor decides to post a specific speed limit until accident area is</td>
</tr>
</tbody>
</table>
**Speed limit category:**

**Definition:**

<table>
<thead>
<tr>
<th>Speed limit category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.5 – Temporary speed limit, variable message sign (VMS).</td>
<td>Speed limits, posted on variable message (road) signs (VMS), in case of a temporarily situation. A typical application is during road works. As in S.4, the speed limit regulation is temporary, but in this case it is displayed on a VMS to enable different speed limits during and outside working hours. These speed limits can be of stationary or movable nature. The latter enables the signposting through use of VMS sign to “follow” when the roadwork moves along the road. The enacted regulation behind a temporary speed limit (S4 and S5) is in each case limited in duration and consequently states the date or time when it expires.</td>
</tr>
<tr>
<td>S.6 – Recommended maximum speed.</td>
<td>These maximum speed recommendations are not enacted regulations but are speed recommendations designed to minimise traffic congestion and enhance traffic safety.</td>
</tr>
<tr>
<td>S.7 – Pre-announcement of speed limits (e.g. towards end of motorways)</td>
<td>Announcing the approach to a speed limit, usually by a fixed signpost with additional text indicating the distance to the actual speed limit.</td>
</tr>
</tbody>
</table>

**Table A4.2. List of SpeedAlert recommendations**

<table>
<thead>
<tr>
<th>N°</th>
<th>Recommendation</th>
<th>Who</th>
<th>Timing (Short, Medium, Long Term)</th>
<th>Priority (High, Medium, Low)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N°</td>
<td><strong>Speed Limit Classification</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Harmonise at the European level speed limit classifications by consolidating the SpeedAlert terminology of fixed, variable and temporary speed limits.</td>
<td>P.A., EC, ECMT</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td><strong>Speed limit data collection, maintenance and certification</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Assess technical and economical feasibility of speed limit data collection and maintenance throughout Europe taking into consideration national/local differences (existing infrastructure, organisation, actors, decision-making process, legal aspects…) by means of appropriate public-private partnerships (PPP)</td>
<td>EC-leading P.A. Map maker, infrastructure operators</td>
<td>short</td>
<td>high</td>
</tr>
<tr>
<td>3</td>
<td>Establish a joint European roll-out plan to organise speed limit data collection, maintenance and certification involving public sector and private sector (infrastructure suppliers, map makers, automotive industry, and service providers)</td>
<td>P.A., map makers, infrastructure operators</td>
<td>short</td>
<td>high</td>
</tr>
<tr>
<td>4</td>
<td>Develop a standardised data model for speed limit information with respects of all different speed limit categories</td>
<td>map makers, service providers, P.A. support</td>
<td>short</td>
<td>medium</td>
</tr>
<tr>
<td>5</td>
<td>Harmonise access to speed limit data (static and variable) available from national/local sources, thus laying the groundwork for the availability of pan-European road data (among others speed limit data).</td>
<td>P.A., infrastructure operators, service providers and map makers</td>
<td>long</td>
<td>low</td>
</tr>
<tr>
<td>6</td>
<td>Develop adapted procedures and mechanisms to optimise maintenance operations of speed limit data (static and temporary) and reduce update process time from real-word changes to the integration into speed limit data infrastructure</td>
<td>P.A., infrastructure operators</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>No</td>
<td>Recommendation</td>
<td>Who</td>
<td>Timing (Short, Medium, Long Term)</td>
<td>Priority (High, Medium, Low)</td>
</tr>
<tr>
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<tr>
<td>7</td>
<td>Explore appropriate certification procedures and processes of speed limit information with respects to data quality requirement and legal aspects (see recommendation 17)</td>
<td>P.A. with map makers (e-Safety)</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td><strong>Speed limit and digital maps</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Update existing standards of digital map exchange format (GDF) to facilitate integration of all speed limit information into digital maps</td>
<td>Map makers</td>
<td>short</td>
<td>medium</td>
</tr>
<tr>
<td>9</td>
<td>Support market deployment of incremental map updates (e.g. ActMAP concept) to enable cost-efficient and time-efficient provision of static speed limit updates to end-users</td>
<td>map makers, service providers, system suppliers</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td><strong>Provision of variable speed limits</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Assess technical and economical feasibility of variable speed limit provision by means of appropriate technologies (broadcast, dedicated short-range communication...) to end-users</td>
<td>Communication system suppliers, infrastructure operators &amp; service providers</td>
<td>short</td>
<td>medium</td>
</tr>
<tr>
<td>11</td>
<td>Develop standardised infrastructure-vehicle communication to support the provision of dynamic content (variable speed limit, incremental update of static speed limit) with European-wide harmonised service</td>
<td>Communication System suppliers, infrastructure operators &amp; service providers</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td><strong>HMI</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Analyse the different interactions with the driver on the basis of an informative system (audio message, visual display, haptic gas pedal), and integration with other in-vehicle applications (e.g. navigation systems...) by exploiting results from national trials</td>
<td>AIDE IP consortium in-vehicle system providers</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>13</td>
<td>Ensure that the design of the in-vehicle HMI follows the design recommendations specified by the EC, European Statement of Principles on Human Machine Interface* of information and communication systems which are intended to be used while driving.</td>
<td>P.A., system suppliers, vehicle manufacturers</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td><strong>ADAS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Identify additional requirements from ADAS applications with regards to speed limit information</td>
<td>MAPS&amp;ADAS consortium</td>
<td>short</td>
<td>medium</td>
</tr>
<tr>
<td>15</td>
<td>Analyse legal aspects for speed alert applications (informative and voluntary)</td>
<td>PROSPER</td>
<td>short</td>
<td>medium</td>
</tr>
<tr>
<td>16</td>
<td>Analyse legal aspects for ADAS applications with regards to speed limit data</td>
<td>e-safety WG MAPS&amp;ADAS consortium</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>17</td>
<td>Explore how certified in-vehicle speed limit information can be considered as road regulation reference (current reference road signs) * SpeedAlert consortium position ** Vehicle manufacturers position</td>
<td>P.A. with industry</td>
<td>Long* Short** Medium Low* High**</td>
<td></td>
</tr>
</tbody>
</table>

**Business case**
2 SPEEDALERT MAP AND DATA FORMAT ISSUES

2.1 GDF and RADEF

RADEF (Road Administration Data Exchange Format) is a data model and exchange format used by some (mainly national) road authorities, GDF is a node-link based data model and exchange format used by the in-vehicle map providers, and also some authorities.

Important elements of RADEF were adopted for inclusion in GDF in 1998, and are now part of the version 4.0 of the GDF standard.

The representation in terms of Road Elements (edges representing the road network) is in general not the same in map databases that are based on the GDF data model, but of different origin. Also in different versions of the same origin, the representation of a road or street may be different in terms of road elements, even if the geometry of the street itself has not changed. This may be due to changes in other features, or in attributes that relate to the road.

This important fact implies that data exchange between two databases of different origin or version cannot be easily based on Road Elements, let alone a harmonised data model for exchange of speed limit information between various map databases.

Road authorities generally use milepost or reference point systems to reference major roads. In GDF terminology (which was adopted from RADEF) such referencing is called chainage referencing system (CRS).

For roads for which a CRS is defined, authorities will store road attributes, including speed limit information, in terms of these CRS. In-vehicle digital map providers generally have not implemented CRS in their map databases and the underlying data models.
This would be done in the future only if there would be a viable business case.

However, only for major roads CRS are defined, with implies that for the majority of roads, including urban roads and streets, and second level rural roads, this method is not applicable. In addition, recently developed national road databases in the Nordic countries do contain node-edge based topology and chainage referencing in parallel, which would reduce the need for chainage referencing for data exchange.

2.2 On-the-fly location referencing

On-the-fly location referencing was developed as a map-based alternative for table based location referencing as used in TMC (Traffic Message Channel).

On-the-fly means that a location code is created when needed from the map database on the sending side (e.g. a Traffic Information Centre), used in a message, decoded on the receiving side (the in-vehicle system), and matched to the local map database.

The map database in fact takes the place of the location table. Recently, with the AGORA-C method code sizes below 35 bytes on average at hit rates of ~98% have been demonstrated.

Although designed in the first place for telematics applications on wide-band broadcast channels on-the-fly referencing might be explored as candidate for the exchange of speed limit data. This could be a variant of AGORA-C as the requirements are different.

AGORA-C codes are very compact for limitation of bandwidth use, and provide high (98% or higher) but not 100% hit rates, and the method relies on GDF defined attributes (like functional road class and form-of-way), which makes the use of a GDF based map database a prerequisite. For exchange of speed limit data (and other safety-related attributes) code size is less restricted, and other attributes can therefore be used (e.g. more full street names) to replace the GDF type attributes. The method may even be extended with a kind of on-the-fly chainage referencing.

2.3 The ActMAP exchange format

The ActMAP project has studied mechanisms for incremental updating of map databases.

In the developed model a map provider will in the future still provide at regular intervals (e.g. once a year) a full map database, in ActMAP terms a baseline map, as extract of its core map database.

In between two baseline map deliveries, changes in the core map database are extracted by the map provider, and provided as incremental updates to the baseline map, at very short intervals, possibly daily or weekly.

For delivery of incremental updates the ActMAP exchange format was developed, an open format based on the GDF data model, but also different from GDF in various aspects.
It is most likely that such incremental updates will be converted by the map centre of a system vendor to specific updates for its PSF, and then distributed to the end user by a dedicated service.

The ActMAP exchange format has been suggested as a candidate for exchange of speed limit data between public authorities and in-vehicle map providers.

However, just like GDFs of map databases of different origin, or even of different versions of the same origin, do not match, also updates in the ActMAP exchange format can only be used for the specific map database for which they are meant, of a specific origin and of a definite version including previous updates.

Therefore this format is probably not a viable candidate for such data exchange.

2.4 **Polygon based referencing**

A possible method for referencing static speed limits that relate to all roads in an area is based on polygons that reflect the area in question.

This relates to built-up area general speed limits, and 30 km zone specific speed limits. Feasibility of this method, both from a technical and from a economical perspective needs to be demonstrated, especially concerning the integration in the map database of the map provider.

2.5 **Referencing based on speed signs**

Another model for exchange of static specific speed limit data is based on speed limit signs. Although speed limits are a property of the road network, and are modelled in the map database for in-vehicle systems as an attribute of the edges (road elements) of the map database, in principle it should be possible to transfer these speed limits as positions of speed signs.

All signposted speed limits together should constitute a logical system, and it is possible to design software to test a complete set of speed limit sign post information in relation to an up-to-date digital map on consistency, as well as to integrate changes in such set in a digital map database.

The signpost positions could be referenced by an on-the-fly location reference, identical or similar to an AGORA-C type of location reference.

2.6 **Transfer of speed limit data by network matching**

Another technique to exchange data from one digital map database to another is network matching, sometimes also called map matching, conflation or linear alignment.

Based on node matching and edge matching correspondences between two networks are established, especially of network edges.
Attributes that are referenced to an edge in one network can then be attached to the corresponding (or matched) edge in the other network. It is often difficult to achieve complete automatic matching, which means that part of the matching needs to be done manually.

Network matching has been studied, since 1985, in different disciplines, especially in the areas of GIS, cartography, transportation and image processing, and various algorithms have been developed. Further research would be needed to determine if this method could be adequate for exchange of static speed limit data.

2.7 Conclusion concerning data exchange

Several issues regarding data exchange and some methods for this purpose have been discussed.

Definition of a harmonised format for the exchange of speed limit information between (current and future) digital databases of public authorities, in which speed limits are stored and maintained, and map databases of digital map providers, is not straightforward, and especially the referencing to the network needs attention.

Considering the difficulties involved in defining a proper harmonised exchange format, and the fact that even with such format many dedicated conversion programs need to be created and maintained at the authorities side, it may be a more efficient option to allow export in different formats, and leave the task of conversion, at least in the short term, to the in-vehicle map providers, as they are already today using conversion programs to import data from various sources.

The discussed methods (on-the-fly location referencing, polygon-based referencing, referencing based on speed sign positions, and network matching between different map databases) are relevant for the longer term, and need further research and testing in the near future.

In addition, the EU funded EuroRoads project attempted to advance in this area and to create a model for public authorities to supply data in a harmonised way.
Figure A4.1. Overview of a possible speed limit data exchange chain

Figure A4.2. Overview of dynamic speed data exchange
Annex 5.

Additional EVI issues from the final report

1 OBJECTIVES

The aim of the study read:

The aim of this project is to investigate the feasibility of an EU-wide Electronic Vehicle Identification (EVI) system. It will identify and assess the main technical and non-technical issues facing EU-wide implementation, and will provide the basis for decision-making by the EU Member States. This feasibility study will include the definition of and agreement on the “core” functionality of an entry-level concept of EVI supporting and facilitating public applications.

The project addressed fully these issues, and following on from the statement above, the objectives of the project were:

- Identify the requirements of Public Authorities for EU-wide EVI
- Investigate the legal, institutional, operational and socio-political issues for the potential deployment of an EU-wide EVI system
- Investigate the implications, requirements and advantages of using EVI to support potential applications, where possible with input from real-life demonstrations
- Develop options for the architecture for an EVI system incorporating functional, information, physical and communication architectural components
- Identify and review potential technology platforms to support the EVI system
- Examine how a “core” concept of EVI could be developed and enhanced with additional functionalities
- Develop different deployment scenarios and investigate the implications
- Assess the feasibility of EVI with respect to its requirements and economic aspects
- Identify the extent to which consensus exists between public administrations on options for EVI across Europe
- Recommend on actions bringing forward EVI

The EVI feasibility study addressed these objectives through a number of steps. Figure A5.1 visualises the exact description of this process, as set out in the next paragraphs.\textsuperscript{56}

\textsuperscript{56} EVI final report September 2004.
2 RESULTS

2.1 Definition of EVI context and requirements

EVI or specifications of its functionality did not exist. EVI therefore had to be defined in terms of requirements and different options for realisation before it could be assessed.

At the start of the study, the full spectrum of public authority user needs and functional requirements were identified, resulting in a number of potential user needs. These requirements capture what the EVI system ideally should be like and therefore provided an appropriate basis for the feasibility study. The public authority user needs and requirements include all requirements identified, including those that might apply to very specific and advanced EVI options and which come from the need to support sophisticated applications.
2.2 Identification of options for realising EVI

On the basis of the set of requirements, the study identified what technical possibilities exist for realising EVI. For these possibilities, it was important to define EVI in a fashion that is as future proof as possible and that takes into account related non-EVI telematics developments:

- The specifications of EVI should be technology neutral;
- The functional capability level of EVI could evolve and range from very simple to very complex systems including all variants in between;
- Future implementations of EVI could be backwards compatible with older versions;
- EVI could be started as stand-alone enabler that interfaces to telematics modules potentially added to the in-vehicle environment at a later stage;
- EVI could be embedded right from the start in the telematics modules and / or a telematics platform that potentially become an element of the basic equipment of future vehicles.

For the above-mentioned reasons, the consortium defined the key functional variations of EVI that represent the wide range of theoretical possibilities. In addition to the definition of the different functional levels the consortium identified the main options for deploying EVI.

It is noted that the definition of the different options for realising EVI allows to carry out the assessment rather than to predefine any blueprint of EVI. Any real implementation of EVI can be a mixture of the identified options.

For each functional variation the in-vehicle EVI device and other components have been defined in a modular fashion. This modular definition of the EVI system comprises an EVI core (basic functionality) and optional add-on functionality.

2.3 Assessment of options

During the assessment stage of the study, the feasibility of the short-listed options for realising EVI has been investigated. This investigation established the link between what EVI in theory could be and the formerly defined user needs and requirements that the consortium defined.

For the different functional levels of EVI and the various deployment options it has been investigated how decision making on any of these options would affect how EVI meets the user needs and requirements.

This feasibility assessment included the following aspects:

- Technical feasibility
- Costs and benefits
- Socio-political aspects, including public acceptance
- Environmental aspects
- Legal issues
2.4 Taking the topic forward

The final report that the consortium drafted does more than just present the key findings of the different stages of the study. It also provides a common basis for further discussion at a European level among decision and policy makers to identify if and how the topic could be taken forward.

It will therefore present the conclusions of the EVI feasibility study and recommend possible next steps.

3 ACHIEVEMENTS

3.1 User needs, requirements, sensitivities and arguments used

The project identified the public authority user needs and requirements for EU-wide deployment of EVI. The consortium received clear indication that all relevant arguments in favour or against certain options for realising EVI, or not to, are captured by this study. These identified arguments include those brought forward by external stakeholders and constitute a checklist of considerations that have to be taken into account by any further decision-making process.

3.2 Architectures, implementations and technologies

The project defined functional, physical and communication architectures for implementing EVI that are modular and that allow an implementation of EVI that is relatively simple which can evolve into more sophisticated EVI systems, thereby extending EVI's functionality.

With respect to the logical information architecture of EVI, the consortium recommends to define a minimum set of EVI device data that is based on an existing directive (99/37) and that comprises one unique identifier.

It is subject to discussion and consensus finding if and how the VIN should be supplemented in this respect. Within the scope of this directive, different definitions of any mandatory minimum set of in-vehicle EVI data could exist.

Within the consortium two views emerged as to the mandatory inclusion of additional data on:

- Public authorities that can envisage full exploitation of the EVI data are in favour of a small set of static vehicle data to be stored in the vehicle, in addition to a unique vehicle identifier for the following reasons:
By storing the set of vehicle (component) identifiers in the EVI device, a fast and simple cross-check of the vehicle status is possible, hereby increasing the reliability of the identified vehicle’s identity;

Support to specific applications even in split seconds makes a wide range of applications more efficient and more effective and could reduce system costs for several applications;

Increase possibility to identify cross-border traffic.

Other Public authorities that are mainly responsible for the registration process are in favour of limiting the mandatory in-vehicle EVI data to one unique identifier only for reasons of cost and complexity.

The project recommended defining a mandatory version of EVI (via EVI minimum requirements and specifications) that is relatively simple and cheap to implement and install.

More sophisticated versions of EVI, if compliant to the minimum mandatory system specifications, could be implemented on a voluntary basis and would be subject to decision-making by Member States and / or the industry.

It was recommended to require any EVI system to support communication with moving vehicles; lack of such support would impede efficient operation of a range of important potential applications based on EVI.

It was concluded that for the realisation of EVI, suitable technologies exist, or could be developed, that allow an implementation that meets the requirements identified.

3.3 Deployment scenarios

The project defined two plausible deployment scenarios. It concluded that if EVI is to be deployed EU-wide the following should be taken into account:

- Equipping the vehicle with EVI should be mandatory.
- The implementation base should be as wide as possible, and all vehicles, new and old, in all EU countries should be equipped.
- A clear and up-to-date specification of the minimum requirements of the EVI system should exist.
- Publicly available and standardised specifications should exist on functionality, security and interoperability of EVI.
- It is recommended that a certified network of manufacturers and issuers be established.
- A certified organisation or network of organisations for type approval should exist or be established.
3.4 Assessment of feasibility of options for realising EVI

The consortium assessed feasibility of EU-wide deployment of EVI on the following aspects:

- Technical feasibility.
- Costs and benefits.
- Socio-political aspects, including public acceptance.
- Environmental aspects.
- Legal issues.
- Institutional impact.
- Risks and analysis what happens if EVI is or isn’t taken forward.

With respect to the assessment categories above, the project derived the following key results and conclusions:

- Decisions that need to be taken on the different options for realising EVI are not precluded as a consequence of technical issues.

- EU-wide deployment of EVI requires organisational modifications that guarantee that the EVI device can be manufactured and issued in a certified and controlled environment. Implementations of EVI should be certified by type approval organisations, preferably at a European level.

- Decisions on mandatory specifications and deployment scenario will affect the analysis of the legal issues that will be relevant. At present however, any decisions within these considerations are not precluded as a consequence of legal issues per se.

- It is concluded that at a European Community level, there are various legal bases for a European framework for adoption of an EVI system under the specific Treaty of the European Union provisions.

- It is concluded that the economic feasibility of EVI depends on the extent to which applications, that can make use of EVI, are going to be deployed in support of policy goals. In principle EVI could support applications that create benefits that compensate or exceed the related costs.

- Benefits and costs will not necessarily be allocated to the same stakeholders. It is concluded that acceptance is affected by decisions that determine who will pay (part of) the costs related to EU-wide deployment of EVI. More specifically it is noted that a lack of support exists among car manufacturers because of a potential risk that this sector will have to carry (part of) these related costs.

Socio-political (and public) acceptance is likely to be influenced by the following:

- Greater compliance with regulations would result in a fairer system that doesn’t give advantages to vehicle owners who do not pay insurance and / or tax requirements

- Increased compliance with road-worthiness test requirements could result in increased road safety as the number of unsafe vehicles on the road decreases
EVI could help realize policy goals such as:

- Improved road safety
- Reduced vehicle crime (including theft recovery)
- Fair road pricing
- More efficient use of the existing infrastructure (including the collection of traffic data)
- Reduced environmental impact of road traffic
- Smoother trans-border traffic in Europe

The rational basis for lack of public acceptance is limited. However perceived fears are likely to remain, particularly in relation to the extent that public authorities may use the system to track an individual, and this will need to be taken into account in any decision making process. Whilst this acceptability is an issue, if properly explained and managed, it could be overcome.

To overcome this potential lack of public acceptance, it is recommended to give priority to the communication of the concept to society. In this context it should be considered if EVI should be communicated as stand-alone system or if it should be presented in combination with an application that the public could understand and accept (e.g. theft recovery and increased safety).

The project concludes that the environmental impact of EU-wide deployment of EVI would be limited though mainly positive. The consortium identified a number of risks if the topic is taken forward. A step-wise approach would allow active management of the risks and evaluation by decision makers at critical milestones. In the event that the topic is not taken forward at a European level, incompatibility of individual systems across Europe that envisage realising similar functionality for identifying vehicles would be a major risk.

Related developments on this topic elsewhere might give the lead to other regions of the world making it more difficult to ensure that European requirements and interests are taken into account.

4 OVERALL CONCLUSION AND TAKING THE TOPIC FORWARD

The project concluded that EVI potentially brings many benefits that are difficult to commercialise but of key importance to society. This feasibility study could not pre-exclude neither presume specific implementations and applications. Instead it clearly shows that different feasible options for implementing and deploying EVI exist. As a result the cost-benefit analysis is not based on a detailed business case of an optimised implementation of EVI in support of specific applications, but it gives a conservative estimation of generic benefits and costs.
Many additional benefits of EVI that could be realised by means of more specific business cases are not readily amenable to quantitative analysis without making assumptions on optimised implementations of EVI in support of very specific applications but contribute to a good case for EVI. For this reason the project considers EVI to be an important topic that should be given priority by national and European decision-makers.

Public authorities across Europe, who did not directly participate in this study, indicated to the project that they had a clear understanding of the concept of EVI and that in their opinion EVI potentially would have a positive effect on road safety, vehicle registration efficiency, and traffic management. For this reason, these authorities also support a process that takes the topic forward at a European level. The project experienced strong consensus on the position that the EC should take the lead for the very next steps.

Given this conclusion it is recommended an EVI work plan be prepared at the European level. For the drafting of such a work plan, as well as for its realisation, it is considered crucial that the EC takes the lead in the very next steps. It is noted that explicit support by specific Member States and / or the HLG on Road Safety would facilitate such process. Several elements of such a work plan will require co-ordination at a European level, whereas others can be carried out and coordinated at a national level.

It is recommended that the work plan consist of several stages whereby at milestones during the process decision-makers can decide to continue, stop, or modify the approach.

It is recommended to define specific items in the EVI work plan that could be carried out separately by consortia and / or working groups. This approach allows the coordinating entity to control and select specific projects that help in realising the different steps of the EVI work plan.

*Figure A5.2* gives an overview of steps that should be part of the work plan.
In Figure A5.2 “policy evaluation” is referring to both the decision making process at the level that is coordinating the EVI process as well as on the official decision making level by the national governments and the Council of Ministers.
5 ADDITIONAL REFERENCES IN THIS ANNEX
