Deliverable 1
State of the Art report

Version number 1.0
Lead contractor TRL
Due date 24.02.2012
Date of preparation 09.03.2012
Authors

Peter Vermaat, TRL
Jean Hopkin, TRL
Kiliaan A. P. C. van Wees, VU Amsterdam
Freek Faber, TNO
Stefan Deix, AIT
Philippe Nitsche, AIT
Kammer Michael, AIT

Project Co-ordinator

Freek Faber
TNO, The Netherlands Research Organisation

Phone: +31 888 66 84 21
Email: freek.faber@tno.nl

TNO
Van Mourik Broekmanweg 6
PO Box 49
2600 AA Delft
The Netherlands

Copyright: COBRA Consortium 2012
## Revision and history chart

<table>
<thead>
<tr>
<th>Version</th>
<th>Date</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>2012-11-16</td>
<td>PV – Setup document</td>
</tr>
<tr>
<td></td>
<td>2012-01-03</td>
<td>Incorporated contributions from TNO (international standards, developments in US and Japan, cooperation),</td>
</tr>
<tr>
<td>0.2</td>
<td>2012-01-12</td>
<td>Incorporated contributions from AIT (European projects and impact analysis)</td>
</tr>
<tr>
<td>0.3</td>
<td>2012-01-17</td>
<td>Updated scoring for applications from previous projects, Incorporated contribution from VU Amsterdam</td>
</tr>
<tr>
<td>0.4</td>
<td>2012-02-13</td>
<td>Added heading numbering, Further project details, Added section on scenarios and deployment road maps, Included section from AIT on sensors.</td>
</tr>
<tr>
<td>0.5</td>
<td>2012-02-21</td>
<td>Revised text on legal issues, additional text on projects and vehicle sensors, overall summary, Incorporated comments from TNO.</td>
</tr>
<tr>
<td>0.6</td>
<td>2012-02-23</td>
<td>Incorporated amendments from TR Technical Review</td>
</tr>
<tr>
<td>0.9</td>
<td>2012-02-23</td>
<td>Draft for TNO review</td>
</tr>
<tr>
<td>1.0</td>
<td>2012-03-09</td>
<td>Incorporated additional comments and material from TNO, AIT and VU Amsterdam Draft for client review</td>
</tr>
</tbody>
</table>
Table of contents

Revision and history chart ................................................................. ii
Table of contents ............................................................................. iii
1 Introduction .................................................................................... 4
2 Cooperative Applications and Services ........................................... 5
3 Industry initiatives ........................................................................... 39
4 National and European developments ............................................ 41
5 Developments outside Europe including in the US and Japan .......... 48
6 Assessing the Potential of Cooperative Systems ............................. 52
7 Main points from the review............................................................ 61
8 References ....................................................................................... 65
9 Appendix 1: Long list of Cooperative Services ............................... 69
1 Introduction

This is the first deliverable of the ERA-Net COBRA project. COBRA is a project advising/supporting decision makers in the context of Cooperative Systems which is funded in the ERA-Net Road programme entitled ‘Mobility: Getting the most out of Intelligent Infrastructure’ and funded by National Road Administrations from Belgium, Switzerland, Germany, The Netherlands, Norway, and the United Kingdom.

This report identifies and describes the current state of the art with respect to Cooperative Systems. COBRA is providing support for decision makers on Cooperative Systems. This deliverable has the following objectives (from the Statement of Work agreed with the Customer):

1. What Cooperative Systems applications exist or are already being actively implemented
2. What Cooperative Systems technologies and applications are already in development and are inevitable
3. What Cooperative Systems technologies and applications are likely to become feasible in the medium to long term
4. Establish what costs and benefits have been previously identified and evaluated within both the European and wider international contexts
5. Establish what cost benefits analysis has already been undertaken by other projects and how relevant these are given our current understanding of future developments
6. Inventory of existing legal frameworks

As this looks at work that has already been undertaken, significant reference will be made to recent related research projects. Where appropriate, the report re-uses text from existing reports, with permission of the copyright holder. Where sections of other reports have been re-used, this is indicated with footnotes. In particular, use has been made of the following projects:

- SMART2010/0063 Defining the required infrastructure supporting Cooperative Systems, September 2011
- SMART2010/0065 New Services Enabled by the Connected Car, July 2011
Part 1 Cross-cutting themes

2 Cooperative Applications and Services

A number of EC-funded and other projects have over the last few years identified and prioritised the services which become possible with cooperative systems. In this section we will analyse the services identified in a selected number of these reports and perform a meta-analysis to arrive at a consensus view of those services which are most relevant to road authorities. A composite list of the services identified by the various projects is included in Appendix 1.

The projects included in this meta-analysis are only those which specifically target road authorities or require infrastructure support.

2.1 EasyWay

The EasyWay project identified a total of seven priority services in the following way:

“First, the task group identified the services relevant or very relevant for EasyWay in order to eliminate from the scoring the services, which will not be priorities in EasyWay in any case.

Second, the services regarded as relevant for EasyWay were assessed on the basis of a number of criteria. Any service scoring well on all criteria should be included as a priority service. The most important criteria were the ones on TERN relevance, contribution to road operators/authorities and the policy impacts.”

Source: EasyWay, 2010

The initial list comprised 47 services in three categories (Safety: 21, Efficiency: 10 and Value Added Service: 16). The first phase reduced these to 19 (11, 4 and 4 respectively), and the second phase to the seven services listed below:

- Hazardous location notification (safety)
- Traffic jam ahead warning (safety)
- Road works warning (safety)
- Decentralised floating car data (efficiency)
- Traffic information and recommended itinerary (efficiency)
- In-vehicle signage (including speed management) (efficiency)
- Automatic access control/ parking management (including Intelligent Truck Parking) (Value Added)

2.2 SMART2010/0063 - Defining the required infrastructure supporting Cooperative Systems:

This project investigated the infrastructure which would be required to support future Cooperative services. As part of the process, potentially relevant services were identified and prioritised. From a long list of 66 cooperative services/applications, a short list of the top 15 applications was chosen. The services were categorised into Safety, Efficiency and Comfort, which coincide with Safety, Efficiency and Value Added in EasyWay.

The long list of services was derived principally from the COMeSafety project, with additional input from EasyWay (2010), COOPERS (Services Deliverable D13), CVIS (20010b Deliverable D.DEPN 5.1 Costs, benefits and business models, Version 31), SAFESPOT (Data from “Cooperative Systems – List of services”), PREDrive C2X (Deliverable D4.1),
FOTSIS (Data from “Cooperative Systems – List of services”), and DRIVEC2X (Data from “Cooperative Systems – List of services”). The long list of services was then analysed by the project team and a prioritised list of services arrived at. The ranking produced was based on the following three aspects:

- the EU wide implementation (plans)
- the technical maturity (or in other words, the next steps to implementation)
- the expected impact in terms of road safety, traffic and energy efficiency, and comfort

The list of 15 services was:

- In-vehicle signage (Safety)
- Road works warning (Safety)
- Wrong way driving warning (Safety)
- Decentralized floating car data (Safety)
- SOS service (Safety)
- Automatic access control / parking management incl. ITP (Efficiency)
- Vulnerable road user warning (Safety)
- Traffic information and recommended itinerary (Efficiency)
- Post crash warning (Safety)
- Traffic jam ahead warning (Safety)
- Hazardous location notification (Safety)
- Enhanced route guidance (Efficiency)
- Obstacle on driving surface warning (Safety)
- Car breakdown warning (Safety)
- Insurance and financial services (Comfort)

2.3  **Smart2010/0065 – New Services Enabled by the Connected Car**

This project, which ran alongside the Smart2010/0063, but was executed by a different team of researchers (even though the lead organisation in both cases was TNO) undertook a stakeholder consultation exercise which *inter alia* asked the stakeholders to identify the most important services which would be enabled by the connected car. The stakeholder group was wide ranging taking into account many interest groups, including road operators. The project team identified a long list of 22 services which could be enabled by the connected car, and asked the stakeholder groups to rank them in importance. The survey was done on-line and attracted 58 responses. The highest priority services identified were:

- Real time travel planning and route optimisation;
- Incident warning;
- Hazardous location warning;
- Dynamic traffic management;
- Personal travel assistant;
- Tracking and tracing of hazardous and valuable goods;
- Cooperative collision warning/ intersection control warning.

2.4  **Cooperative Vehicle Highways Systems: Implications for the HA**

The UK Highways Agency (HA) was a member of the CVIS project. The technical content of the HA contribution to CVIS was subcontracted to TRL. Following the completion of the CVIS project, TRL was contracted to write a report to the HA on the implications of Cooperative Systems for the HA. In preparing this report, TRL analysed 40 cooperative applications and identified those which were of particular interest to the HA. The analysis scored each application on the following criteria:

- Potential societal benefits
- Definition of Overall business model
2.5 Priority Applications

In order to determine the bundles of services which would be most relevant to analyse in the next stage of the project, the priority applications identified qualitatively in each of these studies were listed and the number of times each one featured was counted.

Table 1 lists the applications that were identified as priority applications in each of these studies. The last column indicates the number of studies identifying each one as a priority, which indicates a measure of consensus on the priority applications. Using this approach, four applications are identified as having high priority. However it is important to recognise that this is a very qualitative assessment of the priorities, and is not based on any form of business case analysis.

In the case of the enhanced routing application, the actual service is identified in a number of ways in the various reports; some separate out the various elements into separate services, others combining some or all related services. This group of services fall into the efficiency category, and hence address one of the key aspects of EC ITS policy, namely environmental improvement.

The other group of services identified as a priority is various services providing warnings of potential hazards ahead. Cooperative hazard warning systems are often divided into multiple distinct services, e.g. traffic jam ahead warning, obstacle on driving surface warning etc. While aspects of the services have common characteristics (necessity to detect a hazard, evaluation of hazard, communication to interested parties), the detail of each step can vary from service to service. Various studies have shown that to derive maximum benefit from cooperative systems, the bundling of services is desirable and indeed without this bundling the costs of implementation may exceed the benefits derived - see for example CVIS (2010b) and the Intelligent Infrastructure Working Group (2010). Bundling, however, introduces additional complexity both in terms of business models and assessing the costs and benefits. This issue is discussed further in Section 6.1.1.

An important service which is identified in two reports is in-vehicle signage - sometimes combined with intelligent speed adaptation (ISA). In-vehicle signage is known to be of particular interest to road authorities, keen to reduce roadside clutter while at the same time improving the provision of information to motorists and maximising efficient use of the roads. In-vehicle signage has the potential to contribute to these aims, while at the same time being an enabling technology for ISA.

Another important service which should be considered is the collection of decentralised floating car data. While only highlighted in two reports, this may have been ignored as it does not constitute a service to the motorist, rather it is a service enabler, providing vital data which can be used by service providers to provide a wide range of other services. Once the principal of collecting floating car data is established, it enables a wide range of further data collection from the vehicle’s on-board sensors, in turn enabling further cooperative services like road condition monitoring, ice warnings etc.

One of the studies examined (Wilmink and Schuurman, 2011) suggested that ecodriving coach may be one application that has greater short term potential than others (drivers are provided with feedback that enables them to drive more economically, with benefits for the environment, safety and congestion reduction). It is interesting to note that this method of analysing priority applications has not identified ecodriving as having high priority.
### Table 1 Priority applications identified in key projects

<table>
<thead>
<tr>
<th>Service Description</th>
<th>Category</th>
<th>EasyWay</th>
<th>SMART 63</th>
<th>SMART 65</th>
<th>Score (excluding CVIS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic information and recommended itinerary</td>
<td>Efficiency</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Traffic jam ahead warning</td>
<td>Safety</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Hazardous location notification</td>
<td>Safety</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>Road works warning</td>
<td>Safety</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3</td>
</tr>
<tr>
<td>In-vehicle signage</td>
<td>Safety</td>
<td>X(^2)</td>
<td>X</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Enhanced route guidance</td>
<td>Efficiency</td>
<td>X</td>
<td>X</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Intelligent Speed Adaptation</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Automatic access control / parking management incl. ITP</td>
<td>Efficiency</td>
<td>X</td>
<td>X</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Obstacle on driving surface warning</td>
<td>Safety</td>
<td>X</td>
<td>X</td>
<td>X(^1)</td>
<td>2</td>
</tr>
<tr>
<td>Decentralized floating car data</td>
<td>Data Collection</td>
<td>X</td>
<td>X</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>SOS service</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Vulnerable road user warning</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Post crash warning</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Wrong way driving warning</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Car breakdown warning</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Insurance and financial services</td>
<td>Comfort</td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Tracking and tracing of hazardous and valuable goods</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Cooperative collision warning/ intersection control warning</td>
<td>Safety</td>
<td>X</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Eco-Driving Support</td>
<td>Efficiency</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

The consensus view (although not an unambiguous view shared over the projects) which therefore emerges from this analysis of the priorities in this particular group of projects is that the following application bundles have the highest priority for road operators:

\(^1\) Single service called Incident Detection
\(^2\) Includes ISA
1. Traffic information and recommended itinerary with dynamically updated route guidance (enhanced routing)
2. Various forms of hazard detection, avoidance and mitigation.

Further work packages in this project will investigate prioritised service bundles, based on this report, as well as input from stakeholders, to illustrate the challenges posed by cooperative systems for road authorities.

### 2.6 Technologies

Cooperative systems\(^3\) are a novel approach to improving the safety, efficiency and convenience of road transport which emerged in the last decade; they also reduce environmental impacts. Although the approach is new, the technologies used are not ground-breaking; rather they involve an innovative combination of existing telecommunications and information technology-related principles applied in the transportation industry.

While developments in communications, navigation and positioning, and information technology form the core of cooperative systems, other sectors also play a part, such as vehicle engineering and human factors.

IT-related technologies are responsible for data processing, basic decision making and providing information to the driver, via an on-board computer independently of in conjunction with infrastructure or cloud-based processing capability. These activities are managed by a variety of applications installed on the vehicle’s on-board computer. These applications can be installed while the vehicle is in use, thus giving flexibility to the user. Downloading applications can be achieved with wireless communication technologies, which involve the second core element of cooperative systems - telecommunications.

All of the information received or transmitted by the on-board computers takes place using one of the various forms of wireless communication technology available. In order to avoid being tied down to one technology, which may restrict the efficiency or availability of communication, an innovative approach has been developed. This approach combines five common communication technologies and makes the selection of the medium for the upper level applications seamless. This approach is known as ‘CALM’ and is detailed below. The potential of this modular approach is enormous as it does not require changing the applications if new communication technologies emerge.

However the dynamic market for Smartphone (and other consumer nomadic device) applications (commonly referred to as ‘apps’) will also compete for attention. This represents a ‘bottom-up’, ‘garden shed’ approach to developing applications and services in contrast to the top-down command economy and architecture approach represented by CALM.

Following the ‘top-down’, standards approach to technology development for cooperative systems involves one very important requirement, which is their interoperability. In order to fully exploit all the possibilities in cooperative systems, interoperability must be retained at all levels of development. This is particularly important for safety and control applications and for financial transactions. Interoperability will ensure that systems in a vehicle which has been bought in one country will work in other countries, and that they will operate equally as well in vehicles made by different manufacturers. Without interoperability, the market will become fragmented, costs remain high, demand low and the required critical mass of market penetration more difficult to achieve. A range of different types of agreement and contractual arrangement can contribute to achieving interoperability including standards, agreements, common organisational and business models, and legislation. An investigation of interoperability in current European projects identified key points on interoperability which are

---

\(^3\) Much of the text of this section is based on the TRL report on CVHS for the Highways Agency (unpublished) but has been updated to take account of developments in 2011-2012.
summarised here. A common hardware platform has been demonstrated in principal, including communications, positioning facilities and an open operating environment for installing applications in vehicles, at the roadside and in a central facility. However, retaining a common minimum level of interoperability while allowing innovation and competition in the technical arena, will pose a challenge. It is clear that interoperability means different things to different stakeholders – depending on their role this may be technical interoperability, contractual interoperability or procedural interoperability. For road authorities, the key areas where interoperability is vital are likely to be the roadside infrastructure, gathering probe vehicle data and delivering information to vehicles, and the road authorities will need to protect their interests in these areas.

In parallel with this top-down approach however, the market for information systems is now developing differently, without a common hardware platform or common agreements; route guidance systems have achieved widespread deployment and Smartphone-based services have been demonstrated, while some are already gaining a substantial user base (see Section 3.3 for examples. This tendency to bottom-up development on nomadic platforms raises new issues; for example, integration into the vehicle to make use of sensor information available from the vehicle systems. These issues are starting to be addressed by industry (see below).

2.6.1 Architecture

The European Commission’s ITS Action Plan (European Commission 2008a) includes the following proposals for actions on ITS architecture relevant to cooperative systems:

- Support for the wider deployment of an updated multimodal European ITS Framework architecture for intelligent transport systems
- Adoption of an open in-vehicle platform architecture for the provision of ITS services and applications, including standard interfaces. The outcome of this activity would then be submitted to the relevant standardisation bodies.

To fulfil these tasks, the EC-funded E-FRAME project to extend the European ITS Framework Architecture (E-FRAME) to include cooperative systems. The project built on the requirements for cooperative systems which were identified in three key European projects: SAFESPOT, CVIS and COOPERS, and used these requirements to extend the FRAME architecture to include the cooperative system applications and services covered in these three projects. E-FRAME is also tasked with providing advice to stakeholders from public authorities and industry on managing deployment and organisational issues, and identifying requirements for standardisation to ensure interoperability of cooperative systems. E-FRAME was completed during 2011. Further information is available on the FRAME web site (http://www.frame-online.net/node/122).

2.6.2 In-vehicle hardware

An important hardware component of cooperative systems which resides in the vehicle is a computer which is responsible for supervising all the applications and managing the communication with the in-vehicle sensors. In addition to the computer, a GNSS (Global Navigation Satellite System) unit is available for the accurate positioning of the vehicle and in certain system designs there is also a separate router for communication purposes. A set of antennae is needed for communication, although the number and type of the antennae may vary between different applications and systems.

A computing platform can be built in the vehicle during manufacture, after manufacture, or it can be a nomadic platform such as a Smartphone. Requirements for a built-in computing platform of this type have been described in the ELSA European Wide Service Platform (EWSP) (ELSA, 2009). Service platforms similar to that envisaged by EWSP have been created in the FP7 Integrated Project EURIDICE and in the CVIS project. Nomadic and
aftermarket devices have the same basic requirements for running the applications, determining position and providing communications. The performance of these systems components determines which applications the devices can support.

Probably the only visible part of the system for the user will be a screen installed on the dashboard; this is expected to be a touch-screen (due to its low price), although it is not ideal for use while driving. Further research is needed on aspects such as human distraction, the optimal location, size and required interaction from the driver as the design of the Human Machine Interface will be important in maximising its usability.

There are two significant conflicts which need to be addressed with respect to a dedicated in-vehicle computing platform such as that envisaged by the EWSP:

- **Technology timescale differences** between the ICT technology refresh cycle and the automotive technology refresh cycle. Cutting edge technologies (for example smart phones) have a short model lifespan, typically less than a year, and can be obsolescent within 3-5 years. Lifecycles in the automotive industry are far longer; it is not unusual for a decade to pass between design-freeze and the final production for a model of vehicle (usually with a mid-life upgrade), and the on-road lifespan of a vehicle can be a further decade. This means that a significant proportion of vehicles in regular use incorporate technology more than 20 years old. This is combined with a very long "tail" in the use of vehicles where it is possible and legal to continue using vehicles for decades after production ends. (In addition, communication between vehicles and infrastructure will need to take into account the lifecycles of roadside infrastructure - at least 10 – 15 years)

It is reasonable to expect that any service platform providing ICT services into the vehicle will evolve at the rate of the background technology, hence it is reasonable to expect that in future decades, vehicles of different ages will be equipped with different generations of service platforms.

A possible mitigation for this would be to require the in-vehicle platform to be easily and relatively cheaply upgradable, both in terms of hardware and software. This in turn could then be in conflict with the rigorous integration procedures required of motor manufacturers which make technology upgrades time consuming and expensive.

- **Proprietary vs. standardised solution**: In order to provide a certain level of services into the vehicle, it is necessary that the in-vehicle platform must provide standardised application interfaces. On the other hand, manufacturers prefer proprietary solutions to enable them to achieve a competitive advantage over their competitors. Standardised solutions can also stifle innovation, slowing down the rate of technological progress.

Already vehicles do incorporate EWSP-like platforms, but these are of course proprietary to the manufacturers and their suppliers. Examples include the Microsoft Auto operating system, as used in the Fiat “Blue&Me” infotainment system and the Ford Sync system, and the BMW Connected Drive concept. While currently focussed on infotainment and convenience services, they already include emergency assist services, as well as vehicle-centric services like vehicle health reports. It seems likely that different solutions will proliferate and will then be progressively blended and adapted in an evolutionary way, leading to a measure of interoperability.

As manufacturers increasingly include connected car services, there will be increasing resistance to externally imposed, additional, but parallel services.

Nomadic devices are also a possibility for certain warning and information applications. For other time critical warning and active safety applications, due to the complexity of cooperative systems, the requirement to ‘dock’ with existing vehicle systems and the legal
and standardisation issues involved, nomadic devices are less feasible. Whether factory fitted, retro-fitted or nomadic device, the basic interface should not differ substantially as interoperability is key to the success of cooperative systems. This is starting to be addressed by both cooperative industry-led initiatives (see for example the Car Connectivity Consortium, http://www.terminalmode.org/en/agenda/consortium/) and proprietary interfaces (see for example the Ford Sync interface, http://www.ford.com/technology/sync/, which in turn runs on the Microsoft Windows Embedded Automotive operating system).

However it is not inevitable that nomadic devices will dock into the vehicle. In recent years, mobile computing platforms, usually in the form of Smartphones and tablet computers, have developed rapidly. These devices contain the majority of the computing and communications required to host cooperative applications based on V2I, with the important exception of vehicle integration (particularly access to the vehicle’s on-board sensors and systems). They also provide a secure computing environment (applications are not able to affect either the operating system or other applications). Applications traditionally considered requiring powerful on-board systems and commanding a high price, are now appearing for these platforms. See for example the iOnRoad application (http://www.ionroad.com/), currently available in beta version for free on the Android platform, which includes headway monitoring and potential collision warning.

2.6.3 Future Internet Services

A Future Internet development is the move from dedicated computing facilities and resources to Computing as a Service using a ‘cloud’ of computing facilities and resources. It is expected that in a future “Internet of Things” a wide range of systems, subsystems, components, resources, users and service providers will be individually addressable from the internet and play an active part in the delivery of internet based “cloud” services. ‘Cloud Computing’ enables scalability, reliability and adaptability in the future internet. Cloud Computing is not a specific technology, but is rather a concept that can be realised by employing different types of technologies and concepts like a service-oriented architecture and open service platforms. A ‘cloud’ can be defined as follows (Schubert 2010):

```
A ‘cloud’ is a platform or infrastructure that enables execution of code (services, applications etc.), in a managed and elastic fashion, whereas “managed” means that reliability according to pre-defined quality parameters is automatically ensured and “elastic” implies that the resources are put to use according to actual current requirements observing overarching requirement definitions – implicitly, elasticity includes both up- and downward scalability of resources and data, but also load-balancing of data throughput.
```

The facilities or resources ‘in the cloud’ can be storage facilities, computational resources, software applications or service components. These facilities or resources are provided ‘as a service’ to the users through the internet. Users do not have to be aware of the underlying technology and physical network topologies that supports the services. By providing proper interfaces and standards, both technical and semantic, computing, storage, infrastructure capabilities and software can be offered as services.

There is mounting pressure to make increasing use of cloud technologies. However these often benefit strongly from a pervasive internet connection with known latency. There are inherent limitations to the contribution that cloud computing can make to cooperative services, due to the lack or pervasive connectivity and non-deterministic latencies experienced on the communications channels to mobile computing devices. This effectively rules out cloud computing for time-critical (safety) applications, at least with the current status of developments. It is more likely that cloud services could be used by the infrastructure
provider for flexible, elastic storage and computational resources, or for non time-critical applications. See for example the announcement by Telstra and Mercurien reproduced below, which highlights possible applications in transaction processing and traffic management.

### Telstra and Mercurien partner to develop cloud-based traffic management solutions

#### Telstra and Mercurien – developing the market for cloud-based traffic management transaction solutions

3 May, 2011 - Australian transaction software company, Mercurien Limited, and Australia’s leading telecommunications company, Telstra, today announced that they have signed a Memorandum of Understanding (MOU) to jointly investigate and develop local, cloud-based transaction solutions for the transport sector.

With major Australian cities suffering from a broad range of transport issues, from traffic congestion to parking availability, there is a compelling need for both private and public sector enterprises to be able to deploy effective and scalable transport management transaction solutions. The MOU emphasises both companies’ commitment to developing transportation market solutions that take advantage of the latest transaction processing technologies and benefits of cloud-based operating services. Areas to be investigated include: toll-road use, congestion and traffic-flow management.

The new solutions would use Telstra’s Infrastructure-As-A-Service solution and the Telstra Next IP™ network to deliver Mercurien’s world class, web-based transaction platform.

John Paitaridis, Executive Director, Telstra Enterprise and Government said: “Transport management is one of the biggest challenges for local governments today, and also a major focus for private infrastructure enterprises across Australia.

“We will be working closely with Mercurien to investigate new markets for the transport management sector that can best utilise Telstra’s cloud infrastructure and deliver flexibility, scalability, coverage and ease of use for the transport management industry. This is a great example of Telstra enabling market innovation and solutions for one of the most important sectors in Australia’s economy.”

---

**Figure 1 An example of cloud computing developments in the transport sector**

### 2.6.4 Location awareness

A critical element in most, if not all cooperative applications is that the vehicle must be location aware, i.e. it must know where it is. In general, this is achieved by incorporating GNSS into the computing platform. The satellite position allows the vehicle to be placed on a locally stored digital map. It is well understood that GNSS accuracy is variable, and this must be taken into account by cooperative applications. In cooperative systems, autonomous information from stored digital maps and from vehicle sensors is supplemented with cooperative information received via radio links from other vehicles and the infrastructure.

The accuracy required of the location awareness varies with the application; for example, route guidance needs to place the vehicle on the correct road, whereas some safety services will require on-the-lane or higher accuracy.

There is currently only a single, worldwide GNSS system – the US GPS system. However, within a few years alternative, compatible systems will become operational from Europe (Galileo), China (Beidou), and the Russian GLONASS system will be upgraded to full operational functionality and will be made compatible with the other systems. The US GPS system will also be upgraded to higher accuracy and integrity. Using multi-standard receivers will dramatically improve both the accuracy and reliability of positioning systems, even in urban canyons in cities where the current technology can experience significant inaccuracies.
As different applications have different location awareness requirements, the SAFESPOT project (SAfeSpot 2008) used the concept of Local Dynamic Maps. The local dynamic map is a highly dynamic data store with a relation to the road network, which enables storage and updating of objects including type, position and other characteristics, and retrieval of selected information for further processing and situation analysis, like calculation of trajectories, and detection of hazardous obstacles and potential conflicts with other road users. If the object that maintains the local dynamic map is moving, the map window is moving as well, with the object as its centre point. The local dynamic map is constructed on top of a digital map database for ITS applications, and conceived as a four layer structure with increasing dynamics, and specified as a logical object model, which may serve as the basis for specifying the application programming interface, and for its actual implementation. The four layers represent respectively:

1. the static (semi-permanent) digital map database;
2. similar static information that is not (yet) incorporated in the digital map database;
3. temporary and dynamic information (like weather and traffic conditions); and
4. dynamic and highly dynamic information concerning moving objects (vehicles, vulnerable road users and animals).

2.6.5 Sensors

Infrastructure-based sensors

Many cooperative services require reliable real-time data about the state of the network and the traffic on it. This information will typically be provided by a variety of sensors, some of which will be infrastructure-based.

Since the beginnings of automated traffic data collection in the 1920s, fixed sensors technologies have matured steadily and nowadays are able to provide accurate data for a great variety of applications. These include topics such as traffic monitoring and incident detection, person / vehicle counting and classification, toll collection, pavement and structure monitoring, traffic load monitoring (weigh in motion), road weather information systems (RWIS), as well as real time traffic management and operation (e.g. traffic dependent signals).

However, a single sensor device cannot effectively capture all the information necessary for these tasks. As an example, induction loops are among the most common sensors in use today, yet they are unable to give insights into travel time and unless they are deployed close together, are of limited use for incident detection. Therefore a wide spectrum of technologies has been developed to satisfy the diverse requirements for accuracy during bad weather conditions, coverage of multiple lanes or similar.

Intrusive methods essentially consist of a sensor and data storage device placed inside or on the road or pavement. They include the first and most common sensors to be constructed for traffic monitoring purposes. Problematic are the high costs and practical issues (e.g. the disruption of traffic flow) related to their installation and maintenance. The following list briefly describes some of the most important technologies in use:

- Inductive loops / Magnetometer: these devices based on electromagnetic properties provide many basic traffic parameters (e.g. speed, density, gaps, volume) and are among the most common sensors in use for decades. They are insusceptible to weather conditions but suffer from short life expectancy due to damage from passing vehicles. This can make their use expensive.
- Piezoelectric sensors / Pneumatic road tubes: these pressure based devices provide parameters such as weight and speed. The road tube is an especially simple and
cheap sensor, but its efficiency is influenced by factors such as the weather or traffic conditions.

- Strain gauges / Temperature sensors: these devices provide data on the condition of the road or pavement. Their lifespan is greatly influenced by the traffic loads and road temperature.

Non-intrusive methods were introduced to overcome the shortcomings of intrusive sensors. Since they are placed above or beside the road, they minimize disruption to traffic flow during installation and maintenance and are generally more flexible. They can be further classified into active and passive sensors. The former emit energy in the form of electromagnetic or acoustic signals and measure the reflected signal, while the latter only measure the incoming data. The most common technologies include:

- Cameras: video image recorders provide a wide array of traffic parameters (e.g. speed, vehicle type, density, lane changes, queue length) and can be used as input for a variety of image processing algorithms (e.g. for automated license plate recognition, toll collection or incident detection). They provide good lane coverage and are easy to install, but the accuracy is severely affected by the weather, lighting and traffic conditions. Operation can be passive or include active control from a remote position.
- Ultrasonic / passive acoustic sensors: these devices detect vehicles based on received sound waves (ultrasonic devices actively emit sound waves and wait for the reflected signal) and provide data such as speed and vehicle classification. Both types are susceptible to bad weather conditions.
- Active infrared (Laser) / passive infrared sensors: these devices provide data such as speed, volume and vehicle type. They can also be used to assess environmental information, e.g. road surface condition. Modern active sensors can deliver two- or three-dimensional images. Their accuracy is reduced in bad weather conditions but unaffected by lighting.
- Microwave radar: this active device provides information on e.g. volume, speed and classification. It is not affected by weather but complex road geometry may influence its accuracy.
- Environmental sensing stations: these devices provide information about road weather and parameters such as humidity, visibility, wind speed and direction.

Since there is a vast amount of literature dedicated to modern infrastructure sensor technologies, only a brief overview can be given here. More in-depth information is available on-line, with a detailed review given in the “Traffic Detector Handbook” (Klein, Mills & Gibson 2006). Further references and websites are: Martin, Feng & Wang (2003); Minge, Kotzenmacher & Peterson (2010); Pavement & Surface Sensors (2012); Aurora (2012).

Vehicle based sensors

Vehicle based sensors fall into two categories:

- The vehicle as a sensor, used primarily as a means of gathering traffic data
- The vehicle as a platform for sensors

The vehicle can operate as a sensor by regularly reporting its position to a central location. As long as enough data is available, this allows an accurate and contemporaneous picture of both current journey times and congestion hot spots to be built up in real time. While the same information can be derived from infrastructure based sensors, different sensors are required for journey times from those required to detect congestion. As long as the data is made available as part of another service, the cost of collection is also very low compared to the cost of installing a comprehensive network of infrastructure based sensors. A good
example of this is the mobile phone based system used by TomTom – mobile phones are tracked by the mobile networks anyway, so it is a simple additional process to extract traffic flow data as the phones move through the network. As GNSS-equipped vehicles become more common, the same can be achieved with more accuracy by having the vehicle report its position regularly.

The vehicle can also be used as a platform for additional sensors. Modern vehicles are equipped with a wide range of sensors which could be used as a source of data for gaining an enriched understanding of the state of the network. Examples include:

- Vehicle-mounted accelerometers (for example as used by Electronic Stability Control systems) can potentially detect potholes (Eriksson et al, 2008)
- Airbag deployment can be used as a trigger for signalling a potential incident, already used in eCall
- Skid detection systems can detect slippery road conditions (see for example the WiSafe Car project in Section 3.2.1).
- Repeated activation of high braking forces at particular locations could warn about potential accident black spots or indicate an incident
- Repeated high cornering forces could be used as an input to curve speed warning systems

The current state of the art is that the vehicle as a sensor is already being used, and it is expected that this will become increasingly prevalent. The vehicle as a sensor platform is still in its infancy, but as all modern vehicles have a wide range of sensors already fitted, it is to be expected that the use of these sensors will become increasingly prevalent.

### 2.6.6 Communication infrastructure

As mentioned above, one of the core elements of cooperative vehicle systems is the availability of communications infrastructure. This may be Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I and I2V) and/or Infrastructure-to-Infrastructure (I2I). I2I is normally covered by existing technologies. V2V and V2I are more challenging. The mobile environment is non-deterministic and is such that it is currently (and likely to remain so for the foreseeable future) impossible to guarantee the availability or quality of a communications channel at all times and in all locations. Limited bandwidth and interference from other services are also significant issues. Applications depending on the availability of communications channels must be designed to cope with these limitations. The requirements for V2V and V2I tend to be a little different – V2V channels are higher speed but shorter range (typically to support collision avoidance, warning and mitigation applications) which V2I channels are longer range but lower speed, the speed being limited by bandwidth limitations.

There is a variety of technologies available which are suitable for cooperative systems (e.g. cellular system, Dedicated Short Range Communications (DSRC), infrared etc), but none of these can, on their own, provide an ultimate solution. The Communications Architecture for Land Mobiles (CALM) initiative is approaching this problem by combining a few selected communication methods and making the switching between them seamless to the applications. In this way, the availability and the efficiency of the communication channel can be optimised. Due to its modular approach, CALM is not restricted to currently available telecommunication solutions, so any new emerging wireless technology can be included later as its maturity reaches the required level. Due to these advantages of interoperability and scalability, the “CALM way” of communicating is likely to remain and be part of future cooperative systems, although performance will vary with communications throughput.

The various technologies used in the CALM architecture allow systems to make use of the most appropriate communications channel at any particular time. As Smartphone-based applications (or apps as discussed above) start being used in the vehicle, the CALM communications infrastructure may not be the most appropriate. These platforms are
however expected to eventually make extensive use of future high-speed, (relatively) long range channels, particularly LTE, which has the advantages of ubiquitous, wide area coverage coupled with high speed data channels. If efforts to give these devices access to in-car systems succeed, it may become possible that they will be able to make use of the vehicle in-built V2X communications channels, although this will require significant standardisation effort.

Another important aspect of the communication in cooperative systems is the protocol used during data exchanges. As interoperability is very important even at this level, the most obvious choice for a routing protocol is the Internet Protocol (IP). This protocol is used on the internet and thus makes it available for vehicles or the infrastructure to use during their communications. There are a number of versions available, and due to scalability (particularly IPv4 is running out of available addresses) and security issues, the latest (version 6) has been chosen in most of the current cooperative research projects. It is possible that custom protocols would better suit the highly mobile ad-hoc networks inherent in cooperative systems, but due to interoperability and ease of maintenance, IPv6 is seen as the most appropriate.

A common European Communications Architecture has been developed in the COMeSafety Project (Bossom et al., 2008). This is made up of four physically separated sub-systems for the vehicle, the roadside, the central station and the personal or mobile device, which are inter-linked by a communication network. The communication network consists typically of a ‘backbone’ network with a number of ‘edge’ networks and ‘access’ networks. Communications can take place over a wide range of wireless or wired media and it allows both for direct vehicle to vehicle ad hoc networks and infrastructure-based networks.

An important standard for CVHS (Cooperative Vehicle Highway Systems) communications is the 802.11p WAVE (Wireless Access in Vehicular Environments). IEEE 802.11p is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments. It defines enhancements to 802.11 (the basis of products marketed as Wi-Fi) required to support ITS applications. This includes data exchange between high-speed vehicles (V2V) and between the vehicles and the roadside infrastructure (V2I) in the licensed ITS band of 5.9 GHz (5.85-5.925 GHz). IEEE 1609 is a higher layer standard on which IEEE 802.11p is based.

WAVE has been specifically designed to make use of the spectrum reserved for ITS applications. In 2008, the European Commission decided to reserve 30MHz in the 5.9GHz band exclusively for ITS applications. This was formalised in Harmonized Standard ETSI EN 302 571 Intelligent Transport Systems (ITS). Similar spectrum has been reserved by the FCC in the USA.

A number of other communications technologies may be used in CVHS applications, including Wi-Fi (802.11a, b, g and n), Bluetooth, ZigBee, WiMax, UWB etc. These could be included into the CALM architecture, or used in a dedicated fashion.

### 2.7 Service provision models

Service provision models (also referred to as business models and enterprise models) explain how the benefits of cooperative systems are distributed over the stakeholders, and which roles they have.

The SPITS project performed by TNO describes service provision models (SPITS 2011). It distinguished business-to-business (B2B), business-to-consumer (B2C) and business-to-government (B2G) services. Road authorities can have different roles in the provision of cooperative services. In addition to the role as regulator, road authorities can also have a role in the distribution of value and money (as described in value webs). This can be either by financial incentives (tax reduction or subsidies), or by investing in the services themselves. By stimulating the introduction of commercial ITS services, market introduction...
barriers can be lowered. This does require that the deployed services support the required functionality of less profitable functions. The openness of the platform plays an important role.

EasyWay is performing a stakeholder analysis in which it distinguishes the operational roles for road authorities as infrastructure owner, content provider, service provider and user (Schindhelm 2011). The final documentation of the EasyWay stakeholder analysis has not yet been published.

The SAFESPOT and CVIS projects have defined business models for V2V and V2I services. CVIS concluded that the services which are most likely to succeed are those where there is a mutual exchange of values between different actors in the value chain, and that it is important to have a fair distribution of profit generated, based on how much added value is contributed. (CVIS 2010b)

In SAFESPOT, the analysis of cooperative systems for road safety concluded that the business model must be consistent with the nature of systems, open to including other cooperative functions and any type of service in order to increase users’ willingness to pay for the service, as well as being flexible enough to become part of a larger business (SAFESPOT Blade 2010). SAFESPOT concluded that the business model must include all the actors offering solutions including vehicle manufacturers, producers of after-market and retrofit devices, as well as public authorities (either as road authority, road operator or certification body).

2.8 Deployment issues

There have been three significant reports in the last two years dealing with deployment issues from the perspective of the road operator, namely CVIS, SAFESPOT and EasyWay.

The CVIS report (CVIS 2010a) makes the point that at that date, few of the major factors affecting deployment of cooperative systems have yet been defined; these include public demand for safe and efficient movement of people and goods, commercial transport needs and individuals’ needs for personal mobility. This situation has not significantly altered in the intervening 18 months.

A next step in deployment is the cooperative Field Operational Tests (FOTs) which have begun, such as DRIVE C2X. However apart from cooperative traffic information such TomTom HD Traffic Live services (see Section 3.3.2 for details) there are few examples of large scale deployment of cooperative systems.

The SAFESPOT project developed deployment scenarios and a deployment road map for cooperative safety systems (see Section 2.9.4 on the SAFESPOT project). Road authorities in the UK and The Netherlands have also developed road maps as a way of identifying a possible sequence of events and activities to support deployment of future services (e.g. Rijkswaterstaat includes cooperative systems in their ITS road map, which is discussed in Section 2.9.7).

2.8.1 Road operators’ roles in private service provision

The challenge faced by road operators in deploying cooperative systems will be strongly influenced by the decisions on business models. The split between the responsibilities of the road operator and private service providers will vary between countries and even within countries. Those few cooperative applications currently deployed tend to be wholly private services, normally related to dynamic route planning and optimisation. For example, the TomTom Live service uses traffic flow information derived from the anonymous tracking of mobile phone users to allow its customers to avoid congestion by routing around it. A similar service from TrafficMaster uses floating vehicle data from its own customers to measure
travel times and detect congestion, again allowing its customer to route around congestion hot spots.

In both the above cases, both the traffic data and the service using the data are privately owned and run. The major public cooperative service expected to be deployed in the next few years is the eCall Europe-wide emergency response network. This is the first major deployment requiring significant effort from both the public and private sectors – the public sector will be responsible for the provision of Public Service Access Points (PSAPs) and the subsequent emergency response teams while the private sector will be responsible for equipping all new vehicles with appropriate in-vehicle equipment as well as the telecommunications infrastructure. There is a view that eCall will provide a platform for the provision of a wide range of additional services. The eCall service will require a platform containing a significant number of the major components required for other cooperative services (a computing platform, a communications capability, integration into the vehicles systems, but only a very basic user interface), it is therefore possible for OEM suppliers of eCall in-vehicle terminals to provide a generic telematics in-vehicle device that is able to provide both eCall and additional in-vehicle cooperative services.

2.8.2 Balance between in-vehicle and roadside infrastructure

As with the division of roles, the balance between the in-vehicle and infrastructure based services is not clear cut, and again will to a large extent depend on business models. In general it is expected that the road operator will play a major role in the provision of information while the private sector will be the main provider of convenience services.

2.8.3 Relation between impacts and penetration of equipped vehicles and equipped infrastructure

Research on the relation between impacts and penetration of equipped vehicles and equipped infrastructure is at a relatively early stage.

As the systems are new and their specifications have not been determined to any level of detail, impacts can only be assessed on the basis of a number of assumptions on system functionalities, technologies, traffic situation, vehicle market penetration, infrastructure coverage, usage and effects on driver and travel behaviour.

Previous studies such CVIS, SAFESPOT (Willemsen, 2010), CODIA (2008) and the eCall impact study (Francsics et al, 2009) have estimated impacts for a number of different levels of penetration representing different years or stages in deployment (see Figure 2 for an example). Microscopic traffic simulations were used to include the effects of communication. In current studies, these impacts for different penetration have not been translated into a more generic relation between penetration and impacts. Also the diminishing returns involved in equipping a larger share of the road network has not yet been addressed in current studies.
2.8.4 Coping with technology vs. vehicle vs. infrastructure lifecycles

There is a significant deployment issue surrounding the difference in technology lifecycles of IT devices, vehicles and infrastructure.

Technology lifecycles in IT devices, most evident in mobile phones, can be particularly short – the move from state-of-the-art to obsolescence can be as little as 2-3 years or even less. This is extremely relevant here because the platform required for in-car services closely resembles a Smartphone (a general purpose computing device, location awareness, inertial sensors and communications capability).

Vehicle lifecycles on the other hand are significantly longer. The time from design freeze to market availability is typically of the order of 4 years, and vehicle model life is typically of the order of 8 years with a mid-life upgrade cycle. With an average vehicle life of 10-14 years, this means that the technology in a typical vehicle on the road is of the order of 12 years out of date. This is coupled with a very long tail in vehicle lives – it is not uncommon to see 30 year old vehicles still in regular use.

Infrastructure lifecycles are more defined than the vehicle lifecycle, but significantly longer than technology lifecycles. Infrastructure has a planned build/maintain/replace cycle, but it is possible to upgrade the infrastructure as new requirements emerge, if the core infrastructure is designed with upgrade in mind.

There is currently little consensus in how to cope with technology lifecycles, particularly for the vehicle. It is possible to mandate the installation of an open in-vehicle platform at manufacture, for example the proposed European Wide Service Platform, (ELSA 2009), but maintaining backward compatibility as new generations of hardware and software are released is likely to be extremely complex. A possible way forward is to encourage the development of standards on powering and mounting of nomadic devices within the vehicle as recommended in the EC Study on an Open In-Vehicle Platform Architecture (EC 2010), as already being addressed by industry (Ford Sync etc).
2.8.5 Pump priming - who goes first

The potential benefits from cooperative systems are manifest and recognised in numerous studies. However, it is also recognised that many individual cooperative services do no pass a cost-benefit test individually, but clusters (or bundles) of services often do (and this will be further investigated in later work packages of this project). Since the benefits of cooperative services are often societal (improved road safety, reduced environmental impact of travel), there is an argument that road authorities should take a leading role in deploying the infrastructure to support cooperative services, and this is indeed a recommendation of the Intelligent Infrastructure Working Group of the eSafetyForum (IIWG 2010) where Recommendation 6 states: “Road authorities and/or operators should take a leading role in the intelligent infrastructure deployment”. This, however, is a very general aim and will need to be translated into concrete steps with evidence for decisions.

2.9 Scenarios and road maps for deployment

A number of projects have looked at scenarios and road maps for deployment.

2.9.1 European Intelligent Infrastructure Working Group

The European Intelligent Infrastructure Working Group, in concluding its review of the current status of Intelligent Infrastructure and Cooperative Systems, argued that to facilitate future deployment, a common vision is needed on the importance of cooperative systems for each stakeholder, along with business models and a road map which:

- Provides understanding of infrastructure and vehicles and the roles of stakeholders
- Explores common denominators
- Agrees on converging visions and related strategies
- Establishes compatible objectives
- Selects the first generation of cooperative services.

2.9.2 CVIS (Cooperative Vehicle Infrastructure Systems)

The CVIS (Cooperative Vehicle Infrastructure Systems) project analysed possible road maps for deployment of cooperative systems. An aggregated deployment road map was developed using a 'layered' approach to cover the issues in the various stakeholder domains (Figure 3). Deployment factors were identified and ranked, and applications likely to be a priority for short- medium- and longer- term deployment were identified.
Three different scenarios for deployment were analysed with different levels of government involvement, with the market driven by public, commercial and individual interests; the scenarios were: public policy, commercial vehicles and portable devices (Figure 4). Each scenario was analysed using a common structure: driving forces, applications, OBE, RSE, main actors and penetration.

In the public policy scenario, the initiative would be taken by the public sector, providing funding and promoting standards with a European harmonised technology platform including IPv6. Road operators and vehicle manufacturers would provide new communications and
equipment in vehicles and service providers would then build on the opportunity to deliver services using these new channels. Under this scenario, improvements in traffic management, reductions in congestion and improved safety were envisaged. Sub-scenarios based on a strong demand for safety services and a strong demand for mobility services were considered.

The commercially driven scenario envisaged deployment driven by commercial freight and fleet services, with economic and political factors dominating. Private travel would be influenced by policy aimed at reducing CO$_2$ emissions and maintaining a balanced transport system. EU financing through subsidy of ‘clean’ goods vehicles and cooperative infrastructure would encourage development of cooperative services for fleets. Services would include truck tolling on motorways, access control for heavy goods vehicles in urban areas, truck transhipment points and eCall on all trucks and passenger vehicles.

The consumer-driven scenario envisaged cooperative systems driven by consumer services. Hand-held systems were expected to lead deployment, with some consumers preferring OEM-based systems in new vehicles. The electronics and telecommunications industries could therefore have a more crucial role than OEMs. Public support by setting standards for communications and equipment, and encouraging consumer enthusiasm would give manufacturers the confidence to invest. Under this scenario services would be based on on-board infotainment, with facilities to book parking or other services at the destination, and payment services.

The CVIS partners concluded that while this analysis indicated the most significant factors influencing deployment, it did not lead to a single road map. The conclusions are shown below. It is important to note, however, that CVIS pre-ceded the appearance of cooperative services for Smartphones.
Key conclusions from the CVIS analysis of deployment road maps can be summarised as follows:

- deployment is unlikely to begin with sole implementation of vehicle communication systems for V2V applications, due to the long lead time
- deployment may begin quickly if the public sector (European or national) decided to mandate cooperative systems for one or more applications
- an appropriate level of standardisation is an essential pre-requisite
- cooperative system concepts must be defined and accepted by industry, operators, authorities and users
- clear evidence of the usefulness and benefits of cooperative systems must be gathered and disseminated
- a suitable legal and regulatory framework needs to be in place to ensure the broad availability of safe and secure applications
- business models must be found that satisfy all sectors delivering cooperative systems
- organisational models must be found that ensure clear definition of roles and responsibilities and bring together sectors that may not usually work together;
- individual cooperative ITS services must be defined that bring substantial and quick returns for all stakeholders, and that can be bundled together for efficient and rapid deployment;
- both vehicle and roadside equipment deployment needs to take account of the reality of existing equipment, and to find a low-cost entry path that could include portable devices in the vehicle, and the integration of a V2I/I2V communication gateway with legacy traffic management systems
- many different potential pathways to deployment could be taken, with quite different outcomes at least in the short term; these could be driven by the public sector, commercial transport, the consumer market, the telecom sector moving into location-based and ITS services, and by the convergence of connected services in home, work and travel contexts.

Source: CVIS 2010a – D DEPN 8.1

2.9.3 SMART 65: New services enabled by the connected car

The EC Connected Car project used six scenarios to assess the potential impact of developments in future internet and mobility services on society in the EU (TNO and TRL, 2011). The scenarios were used as a tool, rather than an outcome, to assess potential impacts on society and policy relevance, identify the enabling technologies and establish the challenges and risks to be assessed. Scenarios were developed by clustering potential services and service enablers and mapping them onto different real world situations, bringing together combinations of themes which showed the highest levels of interdependency:

- Eco-centric motoring
- Active safety protocols
- Smart transportation
- Mobility integrated services
- Cooperative traffic intelligence
- Agile navigation systems.

Services for connected cars were mapped onto these six scenarios and three ‘waves’ or routes were identified by which the end vision of the scenario might be achieved, with each ‘wave’ being created to be as separate as possible from the others. Services were then ordered into sets describing evolution from simple existing systems to more complex and sophisticated future technologies, and then plotted on a road map which enabled
interconnections and gaps to be identified. The gaps were then used to identify areas for further research.

2.9.4 SMART 63: Defining the required infrastructure supporting cooperative systems

This project looked at three policy scenarios reflecting different roles for public authorities or road authorities (SMART2010/0063). The dimensions of the scenarios were active or passive participation in traffic management on the road network and the role of the private sector in providing information for road users – the scenarios selected were ‘Public active’, ‘Private active’ and ‘Private passive’. The analysis showed that cooperation between public and private sectors is the most cost-effective – i.e. the ‘Private active’ scenario. The actions needed for deployment of cooperative systems were identified, and a ‘most likely’ road map for cooperative ITS was identified, based on a range of assumptions about each group of stakeholders.

2.9.5 SAFESPOT

Scenario analysis in the SAFESPOT project looked at three scenarios: “technology pushed ITS revolution”, “safety as a public good” and “extended traffic management” and investigated the expected status of development for each one by 2020.

The road map envisaged by SAFESPOT as a result of the scenario analysis is shown in Figure 5, indicating a move from driver support at the strategic level with information and navigation through warning systems providing towards driver support at the operational level with time-critical systems and services. The change is facilitated by parallel development and deployment in supporting infrastructure (described as a cooperative platform). Under this scenario, it is suggested for example that cooperative safety warning systems may first be provided on nomadic devices using long-range cellular networks for communication. This would be followed by a transition towards time-critical systems based on both short range and long range communications. While these conclusions were drawn in the context of cooperative systems for improving road safety, these general points are also relevant for other cooperative systems.

![Cooperative system deployment road map as proposed by SAFESPOT (SAFESPOT 2010d)](image-url)
2.9.6 **SPITS**

In the SPITS project in The Netherlands, four scenarios were examined for how the ITS market could look by around 2020 (SPITS 2011). These were defined by different levels of government involvement and the "openness of the ITS business ecosystem" (the extent to which industry partners cooperate and support industry standards). :

- Collaborative ITS (no regulation, open business ecosystem)
- ITS battlefield (no regulation, closed business ecosystem)
- Community ITS (strict and extensive regulation, open business ecosystem)
- ITS silos (strict and extensive regulation, closed business ecosystem)

Three scenarios for the development of the ITS platform were defined:

- Single platform (world-wide)
- Multiple platforms (some services are compatible with several platforms, others only available on one platform – expected to be the way the market will develop)
- Exclusive platforms (no applications are compatible with more than one platform – expected to occur in the first phase, and eventually in different regions of the world).

Most of the services which meet ‘public’ objectives (and therefore the objectives of national road operators) were seen as most likely to be launched in a second ‘wave’. The first wave of services were seen as being commercial services such as insure how you drive, smart navigation and fleet management, with a risk of a number of similar services developing in parallel, and not inter-operable. Importantly, therefore, the services in the second wave would not be able to build on the services in the first wave, unless the first wave were based on an open interoperable platform designed with the requirements of subsequent ‘waves’ of services in mind.

2.9.7 **TrafficQuest Report**

A review of cooperative systems carried out in The Netherlands provides an example of a road map (produced in the context of the RWS Domain Architecture for Road Traffic Management - DAWEG in Dutch) which expects that cooperative systems will have achieved a high rate of penetration by 2020: 70%. The review noted that it is not yet clear how deployment will progress towards this: whether gradually or in bursts. The road map envisaged an evolution from services which inform, then advise, warn, instruct, intervene and finally provide price incentives. See Figure 6 below.
2.10 Standards, Architecture and Interoperability

2.10.1 Standards in Europe

Standards\(^4\) are an essential aspect of cooperative systems, because multiple communicating entities are involved from different manufacturers, and these need to be able to understand each other. A range of aspects of cooperative systems lend themselves to standardisation; some are driven by technical requirements and some by business needs. Key elements for standardisation will be the interfaces between systems, the communications between them and the information that is to be communicated.

Some standards relevant to cooperative systems have already been developed and others are in preparation. Following a proposal in the ITS Action Plan, the European Commission issued a Mandate (M/453) in October 2009, inviting the European Standardisation Organisations (CEN, CENELEC and ETSI) to prepare a coherent set of standards.

\(^4\) The text of this section is based on the TRL report on CVHS for the Highways Agency (unpublished) but has been updated to take account of developments in 2011-2012.
specifications and guidelines to support deployment of cooperative systems across the European Union and report by 2012.

CEN and ETSI\(^5\) accepted this Mandate in January 2010 and agreed a joint work programme. This lists a minimum set of standards necessary for interoperability and other standards and specifications required for cooperative systems; the list covers a very broad range of standards which means that this work will also have an important influence on ITS implementation beyond the immediate scope of cooperative systems. The following key areas are included:

- Cooperative Awareness Driving Assistance (safety)
- Floating Car Data Collection
- Event Driven Road Hazard Warning
- Traffic Management
- Cooperative Traveller Assistance
- Value Added Services

The minimum standards identified at the outset cover the following topics:

- General (e.g. Architecture, Common Data Dictionary)
- Testing
- ITS Applications
- ITS Facilities
- ITS Network and Transport
- ITS Access Technologies
- ITS Security
- ITS Management.

In addition, two new task forces have been proposed for developing basic standards on local dynamic maps and geo-networking ITS, and 5G media dependent functionalities.

The work programme takes account of previous and current standardisation activities relevant to cooperative systems. Figure 7 summarises how current standards activities contribute to the topics listed above.

\(^5\) CENELEC declined the Mandate
Figure 7 Current standards activities relevant to cooperative systems (Evensen K, Fischer H-J, 2010)

Given that the list of the minimum set of standards set out in the work programme includes a total of 68 standards, it recognises that not all of the standards will be published in the time scale required by the European Commission (2012). The work programme also notes that work is envisaged in future to develop further standards beyond this minimum set.
Developing the standards involves liaison and co-operation with stakeholders including road operators and authorities, the automotive industry and Research and Development projects. There is clearly a role for road operators here.

2.10.2 International standards (ISO) and others

In addition to these activities within Europe, in 2010 the International Standardisation Organisation (ISO) agreed to set up a new working group on cooperative systems: ISO working group 18. ISO has also resolved to collaborate with CEN on standards for cooperative systems, in particular to update relevant standards and incorporate the interests of CEN members in ISO standards which are under development. Cooperation with other standards organisations is also planned: an agreement has also been reached with the USA and there are plans to include Japan.

According the mandate, CEN and ETSI have to recognize the CEN/ISO cooperation and the ISO/TC204 activities to date. The cooperation is formalised by distributing the activities and responsibilities to define a minimum set of standards for two selected cooperative V2V safety applications. These standards will make use of existing standards such as ISO CALM, ETSI TC ITS and IEEE WAVE.

ETSI Technical Committee Intelligent Transport System (ITS) has produced a European Standard (Telecommunications series) document. It specifies the architecture of communications in ITS (ITSC) supporting a variety of existing and new access technologies and ITS applications (Draft ETSI EN 302 665 V1.0.0 (2010-03), European Standard (Telecommunications series) Intelligent Transport Systems (ITS); Communications Architecture, DEN/ITS-0020012)

Luis Jorge Romero Saro, Director General of ETSI, presented this programme at a recent conference (Saro, 2011).
2.11 European policy developments

In 2008 a European Commission Communication ‘Action Plan for the Deployment of Intelligent Transport Systems in Europe’ set out priorities for action to speed up and coordinate deployment of ITS on European roads (European Commission 2008a and European Commission, 2011a). The main objectives were to support the development of pan-European services and to help achieve more environmentally friendly, efficient and safer transport. Cooperative vehicle systems were seen as contributing to meeting these objectives in the long term.

One priority area was ‘Integration of the vehicle into the transport infrastructure’, with four proposals for action to promote the development of cooperative systems:

- develop an open in-vehicle platform architecture for ITS services with standard interfaces
- develop and evaluate cooperative systems and assess deployment strategies, including investment in intelligent infrastructure
- define specifications for communications in cooperative systems
- define a mandate for European Standardisation Organisations to develop harmonised standards for ITS, particularly for cooperative systems.

Progress on these actions since publication of the Action Plan has included:

- completion of a study on an open in-vehicle platform architecture (Oehry et al 2010)
- completion of a study on arrangements for ensuring that public and private organisations have access to travel and traffic information on a consistent, fair and transparent basis (ven de Ven and Wedlock, 2011)

---

6 The text of this section is based on the TRL report on CVHS for the Highways Agency (unpublished) but has been updated to take account of developments in 2011-2012.
COBRA – COoperative Benefits for Road Authorities

- completion of research projects on cooperative systems (including CVIS, Coopers and Safespot, which demonstrated applications of cooperative systems) – see Section 4 for further information
- launch of follow up projects involving Field Operational Tests,
- launch of a study developing a toolkit for decision-makers (2DECIDE – see Section 6.1 for further information)
- work on standardisation and issue of the EC mandate on standards for cooperative systems, to which CEN and ETSI responded jointly (as described in Section 2.10.1 above)
- impact assessment
- international research cooperation on cooperative systems.

The European Commission's ITS Action Plan is supported by a Directive (2010/40/EU approved by the European Parliament in July 2010) on the deployment of ITS in road transport. The intention is that the Directive provides a legislative tool for implementing the Action Plan, but legislation will only be used where it is considered necessary. The Directive provides a framework for implementing the Action Plan and for developing supporting specifications on compatibility, interoperability and continuity of ITS solutions across the EU (European Commission 2008b). Cooperative vehicle systems have a key role in this framework. The work programme for developing these supporting specifications (European Commission 2011b) lists the timetable up to 2014 for work on specifications and standards for six Priority Actions; these include two which could potentially support cooperative systems (EU-wide real time traffic information services and road safety related minimum traffic information) and harmonised provision for an interoperable EU-wide eCall.

The responsibilities set out under the Directive include:

- Member States are responsible for ensuring coordinated deployment of interoperable services, including:
  - reliable and up to date road transport data made available to ITS users and service providers
  - road traffic and travel data exchanged between traffic information and control centres in different regions or in different Member States
  - measures to integrate safety and security-related ITS systems into vehicles and road infrastructure and develop safe human machine interfaces
  - measures to integrate different ITS applications, involving the exchange of information and communication between vehicles and the road infrastructure within a single platform.

- The European Commission is responsible for defining specifications for deployment and use of ITS, including integration of the vehicle into the transport infrastructure:
  - integration of different ITS applications on an open in-vehicle platform
  - defining measures to progress development and implementation of cooperative vehicle infrastructure systems (including data exchange mechanisms, availability of data to exchange, standard message format for communication between vehicles and infrastructure, defining communication infrastructure (for exchange of information between vehicles, between vehicles and infrastructure and between components of the infrastructure) and standardisation of architecture

The Directive also sets out arrangements for type approval, and for dealing with privacy and security. The European Commission has already used standards, type approval and legislation to ensure the introduction of some systems in heavy goods vehicles and buses such as Lane Departure Warning (LDW) and Advanced Emergency Braking (AEB). Legislation for eCall is planned; the European Commission could potentially use these methods to require the introduction of other cooperative vehicle systems in future.
In addition, the Directive provides for assistance with implementation from the European ITS Committee (with representatives from Member States) and a high level European ITS Advisory Group with representatives from Member States, local authorities, service providers and other stakeholders. The European ITS Committee was set up in 2011; the European ITS Advisory Group members have been nominated but at the time of writing (February 2012) have not yet met. Clearly the national road operators will have a part to play in implementing some of these actions and will also wish to have an influence on decisions affecting the development and implementation of systems which influence or interact with the services on their road networks, for example through influencing the European ITS Advisory Group.

The 2011 European Commission White Paper (European Commission 2011c) ’Road map to a Single European Transport Area’ lists a number of initiatives relevant to cooperative systems of interest to road authorities. These include:

- Harmonise and deploy road safety technology such as driver assistance systems, eCall, cooperative systems and vehicle-infrastructure interfaces
- Research and innovation on intelligent infrastructure to ensure maximum monitoring and interoperability of different modes of transport and communication between infrastructure and vehicles
- Definition and deployment of an open standard electronic platform for vehicle on board units
- Interface standards for infrastructure to infrastructure, vehicle to infrastructure and vehicle to vehicle communications
- Accelerated deployment of ITS applications to support eco driving.

2.12 Legal issues

2.12.1 Projects addressing legal issues

The legal issues involved in Advanced Driver Assistance Systems (ADAS) have been investigated in several European projects such as the RESPONSE projects, ADVISORS, STARDUST, AWAKE and PROSPER. More recent projects have (also) been focussing on the deployment of cooperative systems (COOPERS, CVIS, SAFESPOT, FEST, eSecurity Working Group, and the eCall Impact Assessment study). Legal issues identified that may affect deployment of ADAS/ cooperative systems primarily will depend on the functionality (type of intervention, inherent limitation, etc.) as well as the technical and organisational embedding of a particular system (concept). These issues may range from traffic regulations (e.g. licencing, type-approval, road traffic codes) to liability, insurance and privacy law. The implications may differ between jurisdictions.

An example of legal issues in this area can be found in the state of Nevada in the USA, where regulations for self-driving cars have recently been approved (see Figure 10).
Nevada approves rules for self-driving vehicles

“The age of self-driven or autonomous cars is here.

Nevada has become the first state in the country to approve regulations that will allow self-driving vehicles on the road in that state.

Some of you will scoff, but the day we see self-driving cars on roads and highways is much closer than you think.

Google has been working on an autonomous car for a couple of years. Back in 2010, it first gave the public a peak at a Toyota Prius it modified with lasers (mounted on the car) and computers. That technology delivered data to the driving system so it computed the speed, direction etc. of the car. In Google’s car, there’s a person in the driver seat or front passenger seat, but they are not controlling the car.

Since then Google has worked with the Nevada Department of Motor Vehicles, automakers, insurance companies and others to develop regulations for self-driving cars. These are the rules for companies to test autonomous cars in Nevada and for general public use.

Initially, when autonomous cars are ready to roll (ok, drive themselves) in Nevada, they will display a red license plate. Someday, when these robo-cars are ready for general public use, they will carry a green license plate.

While Nevada is the first state to establish guidelines for autonomous cars, it is not alone. There are several other states considering bills that would set regulations for robo-cars.

Google has already logged thousands of miles testing self-driving cars. CEO Sergey Brin has said he wants the Google autonomous test car to log a million miles without an accident. “

Source: CNBC, February 17 2012.

http://www.cnbc.com/id/46429663?__source=yahoo%7Cheadline%7Cquote%7Ctext%7Cpar=yahoo

Figure 10 An example of regulations on self-driving cars

In relation to cooperative systems most emphasis seems to have been put on liability and privacy issues (Konstantinopoulou et.al.)

2.12.2 Liability

Liability concerns and cooperative driver assistance systems are often mentioned in the same breath (although this is less often the case for cooperative information systems). (Uncertainty) about the liability implications of introducing ADAS/cooperative technology in road traffic is labelled as a factor that may slow down socially desirable developments in this domain, for example because of potential liability threat for producers, service providers or road managers) - see for example the EU ITS Action Plan identifying liability and data protection issues as one of six priority areas.

The concept of cooperative systems might raise legal questions and might complicate legal disputes. This is for several reasons (SAFESPOT 2010a):

- There are more parties involved, all with their own responsibilities for the proper functioning of elements of a cooperative system.
- Growing technical interdependencies between vehicles, and between vehicles and the infrastructure, may also lead to system failure, including scenarios that may be characterised as an unlucky combination of events (“a freak accident”) or as a failure
for which the exact cause simply cannot be traced back (because of the technical complexity).

- Risks that cannot be influenced by the people who suffer the consequences tend to be judged less acceptable by society and, likewise, from a legal point of view.

Cooperative Systems introduce new players to the scene (e.g. road managers, service providers) and raises specific questions concerning the scope of legal responsibilities of the actors involved.

In this context it also important to realise that, although some areas of law have been harmonised to an important extent (for example type approval standards for vehicles and product liability law), other areas such as liability of drivers/car owners (traffic liability) and road managers (liability for public roads) are still the exclusive domain of national law and substantial differences between national liability systems might exist.

To be able to make a really useful analysis of legal aspects (in particular liability aspects), a clear picture is needed of the functionality and the technical and organizational embedding of a particular cooperative system (SAFESPOT 2010a, FESTA 2008).

- What is the exact functionality of the system (what does it detect, to what extent does the system process this information and what type alert action will be generated)?
- What are the inherent limitations (for example: adverse effect on performance due to weather conditions, implications of a mix of equipped and non-equipped cars, etc.)?
- What will be the technical and organizational embedding in terms of infrastructure support, division of intelligence between cars and/or the infrastructure? And which parties are involved in the collection and processing of data (governments, road authorities, service providers, etc.) and how is this process organized?
- What will be the implementation context? Will introduction be (solely) market driven or will there be regulatory interventions?

It is for this reason that legal issues cannot be dealt with in a generic way, i.e. giving generic answers to generic questions. Useful results may only then be derived if one considers specific cooperative systems as well as application scenarios for them. Ideally, legal aspects should be evaluated based on detailed view of the roles and responsibilities of each actor in each application, what data is exchanged and how they all interact on a technical/functional basis.

Liability concerns will primarily depend on the type of intervention. In its final report the RESPONSE 2 consortium concluded, as a key message, that ADAS systems remain manageable from the legal point of view and that of the user’s viewpoint only as long as they can be controlled and/or overridden by the driver at any time. Problems regarding licensing and liability of producers and road managers are most likely to occur with assistance systems, which cannot be overruled by the driver or which intervene beyond human psychomotor performance limits (e.g. anti-collision systems). Large scale implementation of such systems might call for (substantial) modification of liability rules and accompanying insurance schemes.

Although overrulable and informing systems are less challenging from a liability perspective, it would be over-simplifying matters to conclude that where cooperative systems can be overridden or where cooperative systems are only of an informing nature, liability concerns will be non-existent. This will depend upon the characteristics of the applicable liability regimes and the circumstances of each case (for example, courts will consider any inherent system limitations, taking into account whether the driver was warned about system limitations and whether he reacted appropriately to any such warnings).

Liability of road authorities/managers’ for public roads is governed by national law. Therefore, relevant liability regimes may differ between countries. On a functional/operational level the involvement of Road Authorities/Managers may take different forms. They may be:
1) responsible for road side components of cooperative systems (e.g. RSU, VMS)
2) service provider (providing information to drivers through VMS signs or providing electronically communicated data to equipped vehicles)
3) content provider for third parties.

Liability exposure of road managers/road authorities will depend on the type of role and the national law regime (SAFESPOT 2010a). Liability issues in relation to potentially incorrect information is most likely to arise in the context of safety applications and under 1) and 2) due to the direct link between the road authority/road manager and the end user. Much will depend on the specific circumstances. If the information error meant that the intended warning message was not displayed at all, one could argue that the motorist was, nevertheless, in no worse a position than he often is, namely, of having to drive without advance warning aids, in reliance on his own observation, skills and judgment. On the other hand, in a situation, such as a motorway, where visual aids are commonplace, one could argue that the motorist is induced to place reliance upon them. In that case, the absence of a warning could be interpreted as an indication that there was nothing about which motorists needed to be warned (no news is good news!)

Development and application of commonly agreed (cooperative system specific) guidelines, performance requirements, codes of practice, certification and validation schemes, etc. will be an important strategy to mitigate liability risks (SAFESPOT 2010a, CVIS 2007). These may be seen as the written expression of 'the safety a person is entitled to expect' or the duty of care to be applied by the manufacturer and may also have relevance in other legal contexts (RESPONSE 2, 2004). Such pre-defined standards will give some guidance in assessing liability, because such a written standard may reflect a general consensus of what acceptable levels of safety are. However, they will not be decisive because courts will take all circumstances into account. Other tools for managing liability concerns include model contracts, insurance risk sharing pools and alternative dispute resolution.

2.12.3 Data protection/Privacy

Unresolved issues in privacy and data protection have been identified as a potential obstacle for promoting cooperative systems. Applications and services may be based on the collection, processing and exchange of a wide variety of data, both from public and private sources. Their deployment may also rely on the use of geo-localisation technologies, such as satellite-positioning. The use of location technologies is particularly intrusive from a privacy viewpoint as it enables drivers to be tracked and a wide variety of data relating to there driving habits to be collected. The processing of location data is therefore a particularly sensitive matter involving the freedom to move anonymously, and which requires the implementation of specific safeguards in order to prevent surveillance of individuals and misuse of data ((EDPS 2010). As such, cooperative systems constitute a "(personal) data-intensive area" and raise a number of privacy and data protection issues that should be carefully addressed (SAFESPOT 2010b). The processing of personal data by cooperative systems will in most cases prove to be unavoidable. Furthermore, reasons for including mechanisms which will make it possible to directly or indirectly identify persons may be the possibility to monitor system performance (error trace ability), explore paid added value services and/or enabling car insurers to monitor driving behaviour for insurance policy purposes.

Within Europe, Directive 95/46/EG provides the legal framework for the protection of individuals with regard to the processing of personal data, while Directive 2002/58/EC (which applies to electronic communication services) addresses location privacy specifically, stating that location data can be processed only after being anonymised or after having gained the consent of the user. Directive 95/46/EG describes the minimum standard for data protection that must be guaranteed throughout the EU by national law. The principles formulated in the
Directive (which Member States are obliged to implement in their national law regimes) however do not provide specified conditions under which data processing is permissible. This leaves considerable room for discussion, also in relation to the design and operation of cooperative systems. What type of information may be processed and under which conditions to be in conformity with these principles? The WP 29 Working document on data protection and privacy implications in eCall initiative (WP 29 2006) and the European Data Protection Supervisor (EDPS) Opinion on the ITS Action Plan and Proposal Directive (EDPS 2010) provide some useful insights into these questions. It illustrates the potential impact of requirements that flow from data protection laws for the operational design of cooperative system applications (and added value services) and it stresses the need to consider these aspects early in the design phase.

‘Privacy by design’ should be encouraged at all stages of the processes and in all forms of the processes:

- At an organisational level, privacy should be considered in the definition of the necessary procedures for data exchange.
- Privacy and security requirements should be incorporated within standards, best practices, technical specifications, and systems,
- At the technical level, so called Best Available Techniques (BATs) for privacy, data protection and security in specific sectors and/or for particular purposes should be developed in which the different security parameters that must be implemented throughout the lifecycle of the system would be defined in order to guarantee compliance with the EU regulatory framework.

The EDPS furthermore outlines some of the issues that must be specifically addressed in the design of applications and the architecture of the systems. These issues relate to the data collected, to the interoperability of systems, and to the security of the data.

In order to avoid a massive and inappropriate collection of personal data (article 6(1)(c) of Directive 95/46/EC states that only personal data that are necessary and relevant for specific purposes may be collected and processed) an appropriate classification of the information and data to be processed should be undertaken, taking account of:

- the source of the data (whether from a public source, telecommunication provider, ITS service provider, other operators, vehicle, user of vehicle or other data subjects),
- the nature of the data (e.g. aggregated information, anonymous data, personal data, sensitive data),
- the purpose(s) for which the data are intended to be used, and
- with respect to cooperative systems, it should be clarified which data is pushed/pulled from the vehicle, exchanged with other vehicle and/or infrastructure, and from infrastructure to infrastructure, and for what purposes.

As little personal data as possible should be processed. To the greatest possible extent, the architecture of the applications and systems should be designed in such a way that only the personal data that are strictly necessary for fulfilling the purposes to be achieved are collected.

The eSecurity Working Group (eSecurity Working Group 2010) also made some noteworthy recommendations in relation to cooperative systems, including the following:

- Ensure separation between independent vehicle-based systems and interactive systems. Vehicle based systems should remain under the responsibility of the OEMs and should not be affected by interactive systems
- Ensure necessary standardisation and harmonisation of security solutions
- Validate security and privacy mechanisms for the first generation of cooperative systems in field operational trials
• Undertake research activities on security and privacy issues for the next generation of cooperative systems.

2.12.4 European ITS-Directive

As mentioned in Section 2.11, the ITS Directive was adopted in 2010, introducing a legal framework to help facilitate the introduction of ITS. This Directive is seen as an important instrument for the coordinated implementation of ITS in Europe. Regulatory developments within the framework of the ITS-Directive should be closely monitored to assess their relevance for cooperative systems within the scope of this project.
Part 2 Cooperative systems projects relevant to road operators

3 Industry initiatives

Industry initiatives in cooperative systems can be divided into collaboration activities, R&D projects and commercially available products. A selection of key activities in each of these areas is summarised here.

3.1 Collaboration

3.1.1 CAR 2 CAR Communication Consortium

This is an industry initiative with the following objectives:

- “the development and release of an open European standard for cooperative Intelligent Transport Systems and associated validation process with focus on Inter-Vehicle Communication Systems.
- to be a key contributor to the development of a European standard and associated validation process for Vehicle-2-Roadside Infrastructure Communication being interoperable with the specified inter-vehicle communication standard.
- to provide its specifications and contributions to the standardisation organisations including in particular ETSI TC ITS in order to achieve common European standards for ITS.
- to push the harmonisation of Car-2-Car Communication Standards worldwide.
- to promote the allocation of a royalty free European wide exclusive frequency band for Car-2-Car Applications.
- to develop realistic deployment strategies and business models to speed-up the market penetration.
- to demonstrate the Car-2-Car System as proof of technical and commercial feasibility.”

The communication technology is based on IEEE802.11, with ad hoc networks established between vehicles and between vehicles and infrastructure as they move within range. A series of use cases has been developed including warning of roadworks, avoidance of traffic congestion and approaching emergency vehicle warning.

Further information is available at: http://www.car-to-car.org/index.php?id=5&L=w

3.1.2 FISITA Task Force

In 2009 the Joint World Road Association (PIARC) - International Society of Automobile Engineers (FISITA) Joint Task Force (JTF) was set up with the aim of informing road operators and national roads authorities about the US programme on Connected Vehicles research and Cooperative Vehicle Highway System (CVHS) developments, supporting road operators’ involvement and helping to accelerate deployment by providing strategic advice and policy information and recommending good practice. The task force looked at:

- Recent developments around the world

---

7 For more details on US Connected Vehicle research, see Section 5.1.
3.2 R & D projects

3.2.1 WiSafeCar: weather and road condition warning service

A consortium coordinated by Mobisoft and involving, research organisations in Finland and companies in Luxembourg and South Korea has developed a cooperative weather and road condition warning system. Vehicles transmit real-time traffic and weather data to a traffic service centre which processes the information and transmits it to other drivers. The road condition warnings are for slippery roads. The communications technologies are both short range (IEEE 802.22p) and long range based on mobile phone. The project took place between 2009 and March 2012, and it is anticipated that the system will be made commercially available by 2014 (Traffic Technology Today, January 2012).


3.2.2 Automotive Telematics On-board unit Platform (ATOP) from NXPT

This was an R&D project to develop an on-board unit which would be attached to the windscreen or dashboard, and combined with an RFID tag on the windscreen, GPS and GSM communications, NFC for communications between devices, and over the air provision of secure services. It included a smart card payment system. The system was intended to be future proof. It was being developed for use in the planned tolling service in The Netherlands, which has not been taken forward. Further information about the planned system is available at: www.nxp.com/documents/other/75016515.pdf.

3.3 Commercially available products

3.3.1 Peek traffic: cooperative ITS platform

This is claimed to be the first commercially available cooperative ITS platform. It was developed on the basis of experience in the CVIS, SAFESPOT and Freiøt projects and launched at the end of 2011.

The first application is an intersection safety application which organizes right of way and provides drivers with advice about intersections as they approach them. It is being promoted as an urban application that will enable road administrators, emergency services and logistics businesses an opportunity to increase safety, reduce emissions (including CO2), cut fuel consumption (a reduction of up to 20% is claimed), and enable reliable travel times in urban areas. It is based on communication standards such as 802.11p for real-time exchange of information between vehicles and roadside systems. The platform consists of a vehicle router, a roadside unit and a web-based control tool. Additional traffic management and traffic information services, such as detailed local navigation and parking applications, can be provided on the same platform. Further information is available at:

http://www.imtech.eu/eCache/DEF/26/070.bGfuZz1FTg.html
3.3.2 **TomTom HD traffic live services**

This is an HD real time traffic information which is used to provide a dynamic navigation service with reliable routing and accurate travel time information. GPS and GSM probe collection systems provide historic and real-time speed measurements which are assigned to the road network. The service is available in The Netherlands, Germany, the UK France, Belgium, Switzerland and Portugal. Further information is available at:  
(www.tomtom.com/lib/.../HDT_White_Paper.pdf)

3.3.3 **VINCI Autoroutes real time traffic information service**

VINCI Autoroutes are a private sector toll motorway operator, responsible for the motorways in western and southern France. This is a free Smartphone application which sends the vehicle position information to the traffic centre, supplying the motorway operator with floating vehicle data. In return the user receives a number of personalised services:

- Co-pilotage - locates vehicle, direction of travel, highway reference and km point; displays virtual Variable Message Signs (VMS); provides excess speed alert (not transmitted to police); allows collaborative feedback to signal incidents and the ends of events.
- Interactive map - provides global overview of traffic conditions and services; allows strategic travel decisions to be made; provides on-trip consultation on major traffic alerts with information matched to the vehicle location; information about rest and service areas; allows collaborative feedback regarding services.
- Safety assistance - embedded emergency phone – user is put in contact with the road operator and vehicle location is given; provides safety directions

The app has been downloaded by over 200,000 users, over 80% of whom are using the service.

The costs incurred by the road operator are the application development costs and the operational costs of processing the floating vehicle data and delivering the services to the users. The cost of the devices is borne by the users and the communication infrastructure by the mobile network operators. The road operator benefits from the floating vehicle data (without relying on third parties), which improves the ability to manage the road network, and from an improved relationship with users (by involving them in the information value chain).

3.3.4 **Private eCall services**

In advance of the pan-European eCall service (see Section 4.2.7), some vehicle manufactures offer a private eCall service in some models of car. These include BMW, VOLVO and Peugeot Citroen. In addition, one of the mobile network operators (T-Mobile) operates an emergency call service in conjunction with a number of manufacturers which is available in several European countries. In the USA, the OnStar service provides a similar service.

4 **National and European developments**

National and European Projects involving cooperative systems have been divided into Collaboration, R&D projects and those involving trials, pilots or Field Operational Tests.
4.1 Collaboration

4.1.1 eSafety Support Intelligent Infrastructure WG – final report

The eSafety Intelligent Infrastructure Working Group was one of the working groups set up in collaboration with industry, road authorities and other stakeholders under the eSafety Forum (now renamed the iMobility Platform). The Working Group attempted to define a minimum level of technical infrastructure required to deliver cooperative services. Services to be supported by Intelligent Infrastructure were identified which are likely to become available by 2015 (having consulted National Road Authorities, CEDR and others); these services mainly provide information and warnings. The group identified the mechanisms by which road operators can gain added value from intelligent infrastructure and summarised the results of impact assessment and cost-benefit analysis on cooperative systems carried out in CODIA, eIMPACT and the Vehicle-Infrastructure Integration Program in the USA (see Section 6.2 for further information). Business models were also discussed and the findings on business models for cooperative systems in the SAFESPOT, COOPERS and CVIS projects were summarised. Strategies for infrastructure providers to use to instigate deployment were suggested, with a step-by-step approach suggested; the importance of ‘champions’ was highlighted. The growth of in-vehicle equipment to support services and specific infrastructure requirements for electric vehicles were also discussed. Legal issues, architecture and standards are also discussed. The recommendations for deployment set out the order in which various elements of the deployment process should be carried out, and the role of road authorities and other stakeholders in that process. The group concluded that nomadic and aftermarket devices will have an important role in the next decade because they can be deployed more rapidly than OEM systems. The need for future-proofing of infrastructure was highlighted, given that vehicle technologies can change more quickly than infrastructure providers can upgrade their technologies.

4.1.2 ASECAP, CEDR and C2CCC

Following from the Intelligent Infrastructure Working Group, ASECAP, CEDR and C2CCC established an informal working group in 2011. The aim is to resolve the remaining challenges for cooperative systems and agree on an investment plan for cooperative systems.

4.1.3 FOT-NET

The FOT-Net project aims to create a networking platform for those interested in Field Operational Tests, their set-up and their results. It is promoting the FESTA methodology for assessing the results of Field Operational Tests and is expected to refine this methodology based on recent experiences and to adapt it so that it is appropriate to cooperative systems, Advanced Driver Assistance Systems (ADAS) and nomadic devices. Working groups cover topics such as legal and ethical issues, data analysis, impact assessment, data sharing and incident definition. The project is due to end in 2013. Further information is available at: http://www.fot-net.eu/.

4.2 R & D

4.2.1 EasyWay

EasyWay is a collaboration of almost all EU Member States, focused on deployment of ITS on the Trans-European Road Network; cooperative systems are one part of the remit. The work is co-financed by the European Commission. The effort on cooperative systems is currently in the form of R&D rather than field trials.
The EasyWay expert groups include ICT infrastructure for core ITS services (including cooperative systems) and the EasyWay Cooperative Systems Task Force. This task force has identified issues for large scale European deployment of cooperative systems and identified priority services. It has carried out a stakeholder analysis, focusing on the role of road operators in cooperative systems, and is also working on a benefit-cost assessment of cooperative services. Recent activities were summarised at the EasyWay annual forum, available at: http://www.easyway-its.eu/download/566/4327/.

4.2.2 SMART 63, 64, 65 (2010)

These three projects were carried out for the European Commission (DG Information Society and Media) during 2011.

SMART 63 looked at what the future infrastructure for supporting cooperative systems will look like. In order to identify infrastructure requirements, the project selected and ranked cooperative systems. Applications were grouped according to their requirements for communications and roadside infrastructure. The project also looked at socio-economic impact assessments and road maps for deployment.

SMART 64 was concerned with what is needed to achieve wide scale deployment of automated driving by 2025. It examined technical issues, policy and other issues, and carried interviews with key players. The conclusions covered three main areas where action is needed for deployment to become a reality: the drivers, the technology and the business models.

SMART 65 – European Services Enabled by the Connected Car identified the needs of both public and private sectors for the services enabled by cars being connected to the internet by 2025. It identified the technologies and services facilitated by the concept of a European Wide Service Platform. The project consulted a range of stakeholders across Europe with different roles in providing and using connected vehicle services on future requirements, priorities and issues. Scenarios and road maps for Future Mobility services enabled by the Future Internet were examined in order to identify future research requirements.

A summary of key points on these projects is available at:

4.2.3 COMeSafety2

This project follows on from COMeSafety and is an EC FP7 project being carried out between 2011 and 2013. The activities include updating the ITS communications architecture developed in this first project, to take account of findings in Field Operational Tests in Europe, the US and Japan and to extend it to a cooperative multi-modal ITS architecture; defining common EU-US compatible applications for cooperative safety and sustainability, with coordinated Field Operational Tests; support for the European standardisation process. The project provides a platform for exchanging experiences and methods from Field Operational Tests around the world (Challen 2012, ERTICO 2011). For further information see www.comesafety.org.

4.2.4 eCoMOVE

eCoMove is developing services and applications that will be integrated in an eco-cooperative system: green driving and routing advice, ecodriving support and truck-specific navigation for fleets and services that will enable road operators to balance traffic flows on the urban and inter-urban road network in the most energy-efficient way. The project thus combines eco-driving support with eco-traffic management using the latest vehicle-to-
infrastructure and vehicle-to-vehicle communication technologies. The project is being carried out between 2010 and 2013. For further information see http://www.ecomove-project.eu/.

4.2.5 P3ITS
This project ‘Pre-Commercial Public Procurement for ITS innovation and deployment’ investigated how pre-commercial procurement can stimulate innovation and help public authorities to move towards market conditions for large scale introduction of cooperative ITS services. The project was completed in 2011 (ERTICO 2011).

4.2.6 SEVECOM
Secure Vehicular Communication, an EC FP6 project which started in 2006, with the goal of defining the security architecture of V2V and V2I networks and proposing a road map for integration of security functions in these networks. The project is now complete. Further information is available at: http://www.sevecom.org/

4.2.7 Pan-European eCall
eCall provides automatic and almost instantaneous notification to the emergency services if a vehicle is involved in “a crash situation” and is within a mobile phone coverage area. The European Commission is actively working to ensure that eCall is deployed across Europe by 2015. The technology to be used has now been agreed and the service to deal with the calls is being set up. The European Commission funded an initial assessment of eCall in the E-MERGE project and in 2008, funded an impact assessment which identified the impacts on safety, congestion, and environment, assessed legal and privacy issues, ethical, moral and economic issues and carried out a socio-economic assessment of pan-European eCall (Francisics et al, 2010). Field trials are currently in progress to test the services in the HeERO project (see Section 4.3.6).

4.2.8 GEONET
GeoNet – Geographic addressing and routing for vehicular communication was an EC FP7 project which started in 2008 and was completed in 2010. The consortium had seven partners and their focus was on the exchange of information with vehicles in a particular geographic area which requires reliable and scalable communication capabilities, called geographic addressing and routing (geonetworking). V2V and V2I communications were both addressed in this project. The standard developed in the project (the IPv6-over-Geonetworking adaptation layer) was published by ETSI in 2010 and has since been implemented by several companies and institutes around the world. For further information see: http://www.geonet-project.eu/

4.2.9 Pre-Drive C2X
PRE- DRIVE C2X was an EC FP7 project which started in 2008 and was completed in 2010. The aim was to develop a detailed system specification and a working and a functionally verified prototype. It was intended to be robust enough to be used in future field operational trials of cooperative systems. PRE-DRIVE C2X was also developing an integrated simulation model for cooperative systems, which, for the first time, would enable a holistic approach for estimation of the expected benefits in terms of safety, efficiency and environment.

The project also developed the tools and methods necessary for functional verification and testing of cooperative systems in a laboratory environment, on test tracks and on real roads in the context of a field operational test.
4.3 Field Operational Tests

4.3.1 COOPERS

COOperative SystEms for Intelligent Road Safety project began in 2006 as an EC FP6 project with 39 partners and finished in 2010. Its main focus was defining, developing and testing safety related services, equipment and applications based on vehicle-to-infrastructure (V2I) communication. The services provided in-vehicle information to supplement the information available to drivers through normal observation. The project goal was to enhance road safety by enabling infrastructure operators to provide faster and real time information exchange to drivers related to traffic, weather and road infrastructure etc. The intention was to be able to use vehicles as sources of monitoring data.

The COOPERS system was tested and validated on public roads in France, Belgium, The Netherlands, Germany, Austria and Italy. The testing and validation covered technical aspects of the services and user acceptance, including willingness to pay and driver distraction. The results showed that at all except one of the test sites, drivers involved in the tests found the system useful. Driver distraction and overload was identified as an issue in some situations, and new regulations were recommended to support safe provision of services such as COOPERS.

4.3.2 CVIS

Cooperative Vehicle Infrastructure Systems was also part of the EC FP6 programme and started in 2006 with 60 partners, and finished in 2010. It was intended to design, develop and test technologies required for vehicles to communicate with each other and with the infrastructure (V2V and V2I). The focus was not only on safety related issues, but other convenience-oriented applications (i.e. parking management) were developed as well, with inter-urban, urban and freight applications.

CVIS was tested in seven European countries: Belgium, France, Germany, Italy, The Netherlands, Sweden, and the United Kingdom. The project examined business models, costs, benefits, and deployment road maps. Further information on these is available in Section 2.9.2 and Section 6.2.

4.3.3 SAFESPOT

SAFESPOT was an EC FP6 programme which started in 2006 and was completed in 2010. The consortium had 51 partners and their focus was on preventing road accidents by developing a “Safety Margin Assistant” which extends the driver's awareness of the surroundings in space and time. It was designed to have vehicle-to-vehicle and vehicle-to-infrastructure (V2V and V2I) communication capabilities.

The validation and tests took place in France, Germany, Italy, The Netherlands, Spain and Sweden. The project investigated business models, benefits, costs, and a sustainable deployment strategy. Further information on these is available in Section 2.9.4 and Section 6.2.

4.3.4 SPITS

The SPITS project’s objective was to realise an open, scalable, real-time, distributed, secure, sustainable and affordable platform for cooperative ITS applications, evolving from existing infotainment systems. SPITS was funded in 2009 and run by 13 organisations in The Netherlands. The project was completed in 2011, having developed a scalable and upgradable prototype which was tested on a public road. A market engagement strategy was defined for deploying this open ITS platform. In the process of developing this strategy
the project looked at business models, future scenarios and growth of various segments of the ITS market. The business case for four ITS services was examined and a qualitative assessment of the profitability of a range of others services was carried out. Further information on these aspects of the project is available in Section 2.9.6.

4.3.5 DRIVE C2X

DRIVE C2X is assessing cooperative systems in Field Operational Tests across Europe. The functions being tested include traffic management, local danger alert, driving assistance, and local information services. An important part of the project is the testing methodology and impact evaluation of the cooperative systems on users, as well as societal and environmental impacts – in addition to testing technical functionality. The project is also investigating business models. The project began in 2011 and is due to be completed in 2013 (ERTICO 2011). Further information is available at: www.drive-c2x.eu.

4.3.6 HeERO

The HeERO project (Harmonised eCall European Pilot) is carrying out coordinated pre-deployment pilots of the European eCall service based on the approved eCall standards. The project is preparing the way for deployment of infrastructure to support the pan-European service and is due to be completed in 2013. See www.heero-pilot.eu for more information.

4.3.7 COSMO

This project, COoperative systems for Sustainable MObility and energy efficiency, is a pilot project to demonstrate the benefits of integrating advanced cooperative traffic management services and to quantify the impact on energy efficiency and reduced carbon. Application areas include environmentally sensitive traffic control strategies, eco-driving, and advanced real-time congestion management. The cooperative applications will be tested, using the cooperative systems developed in COOPERS, CVIS and SAFESPOT, at urban sites in Salerno and Gothenburg and on an interurban motorway in Austria. The project will produce quantified specifications for deployment of these systems covering technical, legal and organisational issues, and information on procurement, installation, operation and maintenance. The project began in 2010 and is due to be completed in 2013 (ERTICO 2011). For further information see: http://www.cosmo-project.eu/

4.3.8 Connected Cruise Control

This project in The Netherlands is being carried out between January 2010 and December 2012. Advice to drivers is provided on speed, headway and lane use in response to congestion ahead, based on integrating in-vehicle systems with roadside algorithms with the aim of improving traffic flow. Initially it can be introduced as a retrofit nomadic device to gain market penetration and provide the basis for OEM systems with active vehicle control. More information is available at: http://wiki.fot-net.eu/index.php?title=CCC

4.3.9 SCORE@F

SCORE@F is a Field Operational Test project in France involving a consortium of 20 partners from the automobile industry, road infrastructure operators and providers, telecoms and services, research institutes and a local authority. It aims to prepare for the deployment of cooperative systems. It is focused on road safety and traffic efficiency management, taking into account the use cases proposed by ETSI in its ‘Basic Set of Applications’. The project is developing and demonstrating ‘comfort’ use cases such as cooperative navigation and internet access. It began in 2010 and is due to end in 2013. Tests are taking place on a
private test track and on public roads: motorways, urban and rural roads. The assessment activities include technical assessment of critical safety applications, conformance, interoperability and performance, driver behaviour, driver acceptance, impacts on organisations, business models, legal and organisational issues and socio-economic evaluation. Further information is available at: http://www.easyway-its.eu/download/566/4327/

4.3.10 Aktiv

This project in Germany developed vehicle to vehicle and vehicle to infrastructure communications for future cooperative vehicle applications, focusing on three areas: traffic management, active safety and cooperative cars. It was completed in 2010. Further information is available at: http://wiki.fot-net.eu/index.php?title=Aktiv

4.3.11 DIAMANT

This project is working on vehicle to vehicle and vehicle to infrastructure communications to improve traffic efficiency and safety. A Public-Private Partnership has been set up for rapid deployment of the applications involving vehicle manufacturer, supplier and the state of Hessen in Germany. The applications covered provide information for drivers, warnings for drivers and ‘virtual influence on traffic’. The project began in 2007 and is due to be completed in 2012. Further information is available at: http://wiki.fot-net.eu/index.php?title=DIAMANT

4.3.12 SISCOGA

SISCOGA (SIStemas COoperativos Galicia) was a Field Operational Test in Spain using the existing road network to carry out tests with 100 equipped vehicles during 2010 and 2011. The tests covered V2I and V2V communications and included warnings of congestion, weather conditions and road works and a hazardous incident in a tunnel. Further information is available at: http://wiki.fot-net.eu/index.php?title=SISCOGA

4.3.13 SIMTD:

“The simTD research project is shaping tomorrow’s safe and intelligent mobility through researching and testing car-to-x communication and its applications. The project started in September 2008 and will run for four years.

simTD will put the results of previous research projects into practice. For this purpose realistic traffic scenarios will be addressed in a large-scale test field infrastructure around the Hessian city of Frankfurt am Main. The project will also pave the way for the political, economic and technological framework to successfully set up car-to-car and car-to-infrastructure networking. To achieve those objectives, numerous automotive and telecommunication companies, the Hessian state government and renowned universities and research institutions have partnered up. The Federal Ministry of Economics and Technology, the Ministry of Education and Research as well as the Ministry of Transport, Building and Urban Development are funding and supporting the project.”

Source: http://www.simtd.org/index.dhtml/134f058bbb512d25072t/-/deDE/-/CS/-

4.3.14 EUROFOT

This is an integrated project which has established a common assessment programme for evaluating mature advanced driver assistance systems in real traffic conditions using multiple fleets of vehicles (private and commercial). Eight functionalities have been tested in vehicles provided by a range of European OEMs. These include forward collision warning, adaptive
cruise control, speed regulation systems, lane departure warning, and curve speed warning. The project is due to be completed in June 2012 (ERTICO 2011). Further information is available at: http://www.eurofot-ip.eu/.

5 Developments outside Europe including in the US and Japan

The development of cooperative systems outside of Europe takes place mainly in the US and Japan. These and some other developments in Asia-Pacific are described below as well as the cooperation between Europe, the US and Japan.\(^8\)

5.1 USA

In the USA, the Strategic Research Plan 2010-2014 (see http://www.its.dot.gov/strategic_plan2010_2014) is subtitled “Transforming Transportation Through Connectivity”. This indicates that cooperative systems will have a role to play. The four principal components of the ITS strategic Research Plan are:

1. Connected Vehicle research (see Figure 11);
2. Short-term intermodal research (modal specific research);
3. Cross-cutting research (ITS horizontal action, including standards and architecture);
4. Exploratory research (with a Connected Vehicle Challenge).

There is further attention given to:

- Human factors research;
- Systems engineering (which should result in a document which described the architecture, interfaces and requirements for a system);
- Certification;
- Test environment.

The Connected Vehicle research programme includes ‘safety pilot driver clinics’ in 2011-2012 involving ordinary drivers assessing applications in controlled roadway situations. These are followed by the ‘safety pilot model deployment’ in which data will be collected under live traffic conditions during 2012–2013. Further information is available at: http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm.

The ITS Joint Program Office also gives information on completed projects under the heading “ITS Research Success Stories”, see http://www.its.dot.gov/res_successes.htm. This includes inter alia information on the Cooperative Collision Avoidance Systems initiative (see http://www.its.dot.gov/cicas). There is also a RITA ITS Benefits database (RITA) – see: http://www.itsbenefits.its.dot.gov/.

---

\(^8\) Some of the material in this section is from the TrafficQuest Report (Wilmink and Schuurman 2011)
**Connected Vehicle Research**

Connected Vehicle Research addresses the development and implementation of a fully connected transport system, which uses innovative, multimodal applications, which in turn require a robust technology platform. This platform consists of well-developed technologies, interfaces, and processes that together make the system operate in a secure, stable, interoperable and reliable fashion. The research focuses on the following areas:

- Connected Vehicle Technology
- Connected Vehicle Applications
- Connected Vehicle Technology Policy and Institutional Issues
- Use of Dedicated Short Range Communications

A transport system in which everything is connected to each other will be developed through coordinated research, testing and demonstration, implementation and dissemination. Federal funds are to address research areas that private parties may not address because they are too risky or too complex. Other parties such as states, the automotive industry and their suppliers, and consumer electronics companies are also exploring connected vehicle technologies and applications. The Connected Vehicle research falls under the Intelligent Transportation Systems (ITS) Joint Program Office (JPO) at the Research and Innovative Technology Administration (RITA) of the Department of Transport. The research into vehicle applications focuses on:

- Safety: V2V and V2I communications;
- Accessibility: Real-Time Data Capture and Management and Dynamic Mobility Applications
- Environment: Applications for the Environment: Real-Time Information Synthesis (AERIS)

Source: [http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm](http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm)

---

Examples of projects carried out in the US include CICAS and Safe Trip-21.

The National Highway Traffic Safety Administration has announced that intends to made a decision in 2013 on whether to begin making rules governing 'Connected Vehicle' technology. The decision will be made once the results of pilot studies are available. (Traffic Technology Today 2012).

### 5.2 Japan

Japan considers ITS as the key to an "IT nation", and so ITS is strongly promoted. Coordinating the efforts of the government and the private sector is done by the Highway Industry Development Organization (Hido). Hido oversees new developments and supports new industries. In May 2010, the "New IT Strategy" was published. Both short-term (until 2013) and long-term goals (to 2020) are described. Japan promotes ITS for a variety of policy objectives: safety, congestion reduction, improved logistic efficiency and reduced CO₂ emissions.

In September 2010 the Japanese launched high level task forces on the subjects of e-Government and ITS. The ITS Task Force is examining policy regarding "Green ITS" and "Cooperative Safety Support Systems". This is controlled by the relevant ministries and researchers working in the field of transport and ICT (including the chairman of ITS Japan). Part of the road map (for cooperative systems) includes international coordination and scenarios for system development and deployment. These are mainly in safety systems in (sub) urban areas for vulnerable road users, at intersections and on streets.
There are several much longer programmes to develop cooperative systems. In the Smartway project, started in 2004, several systems have been developed and tested. The next phase being worked on by public and private partners is to get the systems widely implemented. The Smartway systems are designed to make traffic more efficient, safer and cleaner. The Smartway “Fundamental services” are:

- Vehicular information transmission (probes, facility entry/exit management);
- Fee payment (multi-purpose payments, ETC);
- Information provision (internet);
- Information and warnings (driving support information, VICS, warnings and vehicle control, provision of safety information, vehicle controls, automated driving);
- Others (pedestrian support, applications for inter-vehicle communication, applications using wired communications).

The ASV (Advanced Safety Vehicle) project promoted by the Road Transport Bureau of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is also relevant. It involves development of inter-vehicle communication which includes "vehicle intelligence" and introduction of some inter-vehicle communication (V2V) type driver assistance systems. Inter-vehicle communication will provide support when onboard sensors are not sufficient. The fourth phase of the project ended in 2010. One of the goals in this phase was to introduce full-scale autonomous detection type driver assistance systems and some inter-vehicle communication solutions.

Currently, the "Energy ITS" project is underway, which includes working on platooning (for trucks) (Tsugawa & Kato, 2010). ITS spots are being implemented. The Ministry of Land, Infrastructure, Transport and Tourism is installing appropriate roadside systems at some 1,600 locations, primarily on expressways. Automotive manufacturers are developing and marketing in-car systems that provide services to the ITS spots (see also http://wiki.fot-net.eu/index.php?title=Smartway).

Japan is relatively advanced with the introduction of on-board units. In Japan, electronic toll collection (ETC, with V2I communication) is already well implemented, a large proportion of vehicles being equipped with ETC: (Tsugawa & Kato 2010) report that the number of ETC units in the market at about 39 million lies with an average usage of 80%, which has eradicated congestion at toll gates. It continues to promote the greater use ETC. The number of VICS units (Vehicle Information and Communications System - used for dynamic congestion information) stood at 27 million in 2010 (Tsugawa & Kato 2010). The development and production of on-board units is promoted by the government and private parties. Research committees are in place, deciding on standards and specifications. Further a platform is being developed to process data from various sources (FCD, bus location, parking information, disaster information, etc.). Research is continuing to consider which further applications may be possible (e.g. ETC could be used for parking charges).

Japan also has observer status and cooperation status on different EU/US working groups on cooperative systems.

5.3 Other Countries

A number of other countries have research and development programmes. Korea has programmes such as “Connected Car, Seamless Service” and “Smart Highway”. China has a project called “Star Wings” (see Figure 12). Further information is available at: http://wiki.fot-net.eu/index.php?title=FOT_Catalogue).
5.4 Cooperation

The world of cooperative systems is very international. Europe, the U.S. and Japan are seeking closer cooperation. The EU and the U.S. have created a task force, which aims to work towards international standards and joint research in the field of cooperative applications. Also a common methodology for the evaluation of cooperative systems and the exchange of Field Operational Test data is being developed. The goal is to understand what both parties need, and what research programs are underway. This will allow results to be shared, joint working on projects and the implementation of results. There is also an attempt at preventing duplication of research in different countries. Specifically in the field of cooperative systems and (CO$_2$) emissions, there is cooperation between the EU, METI (the Japanese Ministry of Economy, Trade and Industry) and the U.S. (Department of Transportation). To support existing bilateral activities between the EU and the US, and between the EU and Japan, and strengthen trilateral co-operation in working towards standardisation, the ECOSTAND project was established. The project serves as a platform for the continuation and expansion of the EU-US collaboration, and effectively replaces the EC-METI Task Force.

The objective of ECOSTAND is to support cooperation between the European Union (EU), Japan and the United States (US) on a common assessment methodology for determining the impacts of Intelligent Transport Systems on energy efficiency and CO$_2$ emissions. This support will involve the formulation of (i) policy advice, in the form of a road map and (ii) a joint research agenda to identify gaps in the understanding and to propose solutions to enable the methodology to be developed.

Star Wings

Star Wings is a smart navigation system, which enables the user to avoid traffic jams by calculating the shortest route based on real-time probe data from a large number of taxis in Beijing. The first commercial application is now on the market.

The intention is for market partners to further develop the system, and also to expand the system to other cities in China. A portable device is also envisaged. The project also performed simulations which examined how traffic flow was affected by the system. This used information about the behaviour of drivers and real-time traffic information in Beijing. The simulations showed that if the system is used by 30% of drivers the average vehicle travel time for commuters could decrease by 16%. A reduction in CO2 emissions would then be possible.


Figure 12 The Star Wings project
For more information see http://ec.europa.eu/information_society/activities/esafety/intlcoop/index_en.htm. There is also cooperation between Rijkswaterstaat and the California Department of Transportation (Caltrans), and between TNO and California Partners for Advanced Transit and Highways (PATH).

In addition to these activities, ERTICO has launched a Cooperative Mobility Alliance that is bringing together the main actors in cooperative mobility to drive forward the priority actions needed to promote deployment, and to remove deployment barriers. The objectives (ERTICO 2011) are:

- Define reference business models showing costs, benefit, and boundaries for all actors involved in the value chain
- Define implementation profiles for the selection and configuration of standards, core technologies, protocols, APIs, interfaces etc.
- Support the development, validation and application of industry-agreed standards and specifications
- Provide for a scheme to certify the conformity and performance of equipment, interfaces, applications etc.
- Increase awareness of cooperative ITS and its benefits amongst politicians, transport and mobility professionals and the general public.

The tasks for the alliance include defining implementation models for cooperative systems, a case study of end to end deployment of cooperative systems for energy efficiency, and work on issues such as certification and IPR management (Kompfner, no date).

6 Assessing the Potential of Cooperative Systems

6.1 Impact assessment

6.1.1 Methodology for impact assessment

Assessing the impacts of Cooperative Systems generally comprises four main aspects:

- Impacts on traffic safety
- Impacts on traffic efficiency
- Impacts on the environment and health
- Impacts on installation, operation and maintenance costs

From the point of view of road operators, cooperative systems may be expected to provide the following types of benefits, as illustrated in Figure 13.
<table>
<thead>
<tr>
<th>Safety</th>
<th>Congestion</th>
<th>Environment</th>
<th>Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in fatalities</td>
<td>Reduced travel time</td>
<td>Meeting requirements of Air Quality Directive</td>
<td>Reduced signage</td>
</tr>
<tr>
<td>Reduction in injuries</td>
<td>Reduced uncertainty in journey times</td>
<td>Reduced carbon footprint</td>
<td>Reduced costs of buying data</td>
</tr>
<tr>
<td>Meeting casualty reduction targets</td>
<td>Meeting targets for road network efficiency</td>
<td>Reduced noise</td>
<td>Reduced costs of gathering data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Improved capacity of the road network and delay in need for further investment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Reduced operational and maintenance costs/ more efficient use of resources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Potential for raising revenue through sale of information</td>
</tr>
</tbody>
</table>

Figure 13 Types of impacts for road operators

The specific benefits achieved in any one service will depend on the nature of that service. For example the European eCall impact assessment study identified reductions in fatalities and reduced severity of serious injuries, reduced delays (through quicker road clearance) and reduced emissions arising from reduced congestion (Francsics et al 2009). In eIMPACT the impacts of intersection safety identified were reductions in fatalities and injuries and reduced congestion arising from the reduction in accidents.

This state of the art review mainly focuses on the methodology of impact assessment. Further detailed results can be found in the deliverables for the CODIA, SEiSS, eIMPACT projects.

Due to the wide variety of cooperative systems, most assessment projects have considered a limited number of specific systems or clustered into groups of cooperative systems. For example in the EU project CODIA\(^9\), the selected cooperative systems were speed adaptation (V2I/I2V), reversible lanes due to traffic flow (V2I/I2V), local danger/hazard warning (V2V), post crash warning (V2V) and intersection collision warning (V2V, V2I) (Kulmala 2008). The European project eIMPACT\(^10\) selected a more comprehensive set of cooperative systems for in-depth assessment, focussing on Intelligent Vehicle Safety Systems (IVSS), although only two of these (eCall and intersection safety – a primarily urban application providing traffic signal assistance and right of way assistance) involved cooperation between vehicles and infrastructure, which are the applications of most interest to road operators. According to Vollmer et al. (2006), eCall, in-vehicle safety systems such as ESC, advanced driver assistance systems such as ACC, lane keeping support, emergency braking driver drowsiness warning and night vision were also considered for the analyses. In SAFESPOT, the impacts of two cooperative applications involving vehicles and infrastructure were assessed: intelligent cooperative intersection safety, hazard and incident warning due to

---

\(^9\) CODIA: Cooperative systems Deployment Impact Assessment, started January 2008, duration: 8 months.
\(^10\) eIMPACT: Assessing the Impacts of Intelligent Vehicle Safety Systems, started January 2006, duration: 24 months
weather conditions, and speed limit alert (SAFESPOT 2010a). Another project looked specifically at the impact of eCall (Francsics et al 2009).

In general, project objectives, the availability and reliability of data and project resources determine the extent to which cooperative systems are analyzed. Consequently, a reduced number of systems may undergo the full set of analyses. For all systems, there should also be a non-cooperative version, which the cooperative systems can be compared to. In assessment projects, it is common to compare all alternatives to the base or reference case of no such system at all.

CODIA, eIMPACT SAFESPOT and the European eCall impact project all carried out a pan-European impact assessment, grossing up the results from different types of area and road to the 25 European Member States.

The impact assessment results for the two CODIA applications involving infrastructure are shown in Figure 14.

![Figure 14 CODIA - The impacts of two cooperative systems (Source CODIA 2008)](image)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>I2V Dynamic speed adaptation</th>
<th>I2V Reversible lane control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit/Cost</td>
<td>+</td>
<td>---</td>
</tr>
<tr>
<td>Safety</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Efficiency</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Emissions</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Noise</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mobility</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Comfort</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>EU competitiveness</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>ITS industry</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Postponing investments</td>
<td>+</td>
<td>+++</td>
</tr>
</tbody>
</table>

(+++ means very positive, ++ positive, + slightly positive, 0 negligible effect, - slightly negative, -- negative, --- very negative).

Some projects assess the impacts of applications when they are bundled together with others, as well as the free-standing applications. For example SAFESPOT looked at the impacts of speed alert and intersection safety when bundled together (SAFESPOT 2010b).

The Intelligent Infrastructure Working Group (2010) noted that individual services will rarely be economically viable, but that bundling of services may make it possible to achieve a positive business case while providing complementary services to support policy objectives; the need for reliable data on impacts – both individual services and bundles of complementary services – was highlighted.

Bundling was also considered in CVIS (2010b). The conclusion was that the expected benefits of stand-alone personal services and services for freight and fleet operators would not cover the public costs incurred, and that only when commercial, personal and public services are bundled together would the benefits outweigh the costs.
For road operators, bundling introduces another element of complexity to the delivery chain, with more complex organisational arrangements and the additional question as to whether service providers will be entitled to offer applications involving use of infrastructure independent of road operators. However all stakeholders may benefit from sharing information, and therefore see a business case for working together.

Methodologically, bundling also introduces additional complexity in the assessment. Care needs to be taken to avoid double-counting, for example, where there are overlaps in either the benefits or the costs of services that are bundled together.

The assessments do not all use common approaches to quantifying the impacts, which means that results from different studies are not always comparable (see Section 6.2 for a discussion of common values for measuring impacts). In addition some factors, such as health, are extremely difficult to quantify in monetary terms (and therefore difficult to set alongside other impacts that can be monetised).

To date, most of the work on assessing the impact of cooperative systems has been based on desk studies, simulations and estimations by experts. Field Operational Tests will provide empirical evidence of impacts in due course.

The 2DECIDE project is developing an ITS toolkit which will provide decision-makers with support on ITS applications, technologies, legal issues and ITS architecture. It is collating assessment results on impacts, costs, benefits, user acceptance and feasibility for a series of ITS services including cooperative systems (2DECIDE 2010). While this may be a source of information for estimating costs, it does not cover cooperative systems.

Several of the studies have noted that there is no single cooperative system which really stands out as producing substantial impacts (with the possible exception of ecodriving coach reducing emissions by helping drivers and traffic managers to be as efficient as possible on the road using routing advice, influencing traffic signals and providing tips for fuel efficiency); deploying a range of systems, with different effects, appears to be the way forward for achieving substantial impacts (Wilmink and Schuurman, 2011).

### 6.1.2 Assessment of impacts on traffic safety

For the assessment of traffic safety impacts, a common and simple approach is a before/after analysis of accident data. Many studies have been conducted to assess the effects of specific traffic safety measures (cf. Elvik, R. 2009). However, for these analyses, a relatively long period of observation is needed. Moreover, various factors may influence the results, which make them less meaningful.

In the projects CODIA and eIMPACT, safety impacts were assessed by considering three factors (see Figure 15): traffic exposure, risk of collision and risk of collision resulting in injury.
In CODIA, anticipated driver reactions were defined as a starting point. Secondly, the relevant safety mechanisms were selected for each system studied, and the expected changes in driver behaviour were described. Each system was compared to the base or reference case with no system. Thirdly, based on existing knowledge, a numerical percentage value for the change in fatalities and injuries was estimated for each safety mechanism. Figure 16 gives an overview about the phases of impact analysis conducted in CODIA. The estimates were based on references found in literature and other evidence available, such as already available empirical evidence on safety impacts for systems with similar functionality and expert evaluations.

![Figure 16 Schematic picture of safety impact analysis (Kulmala 2008)](image)

Results of CODIA have shown that dynamic speed adaptation systems have the highest potential to prevent fatalities and injuries under the assumption of cooperative systems penetration and traffic exposure in 2030. In general, the cooperative systems showed promising potential to contribute to improved traffic safety.

Further methods to assess safety impacts are related to the analyses of Field Operational Tests, which are large-scale test programmes for cooperative systems. They allow a comprehensive evaluation of data quality, effectiveness and user acceptance. Projects such as TeleFOT or euroFOT (see Section 4.3.14) show the effects of enabling technologies on traffic and provide uniform assessment criteria and indicators. In the FOT-NET project, results and findings of different FOT are published and various methods are harmonised. This source of information will be investigated further to provide data for the COBRA decision tool. Within this arena, the FESTA project has provided guidance on impact assessment for the FOTs to use in carrying out their impact assessments.
6.1.3 Assessment of impacts on traffic efficiency

An indicator for the assessment of traffic efficiency and congestion is travel times at different cooperative system penetration rates. In most common approaches, these times are determined by micro-simulations in SISTM or VISSIM and parameter variations. For each cooperative system to be analysed, specific traffic situations or scenarios should be considered in simulation. For example, these scenarios could be an accident that causes congestion or poor weather conditions (e.g. fog) that suddenly occurs. Driver reactions are then modelled in case of an operational cooperative system (e.g. speed adaptation) compared to the non-cooperative scenario.

The impacts on drivers’ journey times can then be converted into estimates of improved road network efficiency, improvements in capacity and reductions in travel time variability. From a road operator’s point of view, these improvements may make it possible to avoid or at least postpone further investment in road infrastructure, as well as meeting Key Performance Indicator targets for congestion or performance in dealing with incidents.

In the European eCall impact study it was found that the cost-benefit results were extremely sensitive to the methods used for estimating reductions in congestion, because in some areas the congestion savings represented a large share of the total benefits (Francsics et al. 2009). Further work on estimating traffic impacts was recommended, so that the overall assessment could be refined.

6.1.4 Assessment of impacts on environment and health

Environmental aspects include air pollution (CO$_2$, NO$_x$ etc.), noise emissions and emissions, and further lifestyle quality or landscape aesthetics. However, evaluations of effects on the environment are mainly based on a change of driving behaviour or travel mode, which may be caused by cooperative systems. The Intergovernmental Panel on Climate Change (IPCC) published a series of guidelines, such as the 2006 Guidelines for National Greenhouse Gas Inventories that helps to assess on a more global level. For a locally based environmental evaluation, the German Handbook Emission Factors for Road Transport (HBEFA) provides emission factors for all current vehicle categories and for a wide variety of traffic situations. Emissions from road vehicles depend on traffic composition, vehicle speeds or road configuration. The team of the EU project ARTEMIS developed a harmonised emission model for road, rail, air and ship transport to provide consistent emission estimates at the national, international and regional level (André et al.). Instantaneous emission models require precise information on vehicle operation and location. Traffic micro-simulation modelling is able to provide an appropriate level of input.

Considering a change of driving or mode choice due to cooperative systems, these emission models can be used to estimate direct and indirect effects on the environment. In the CODIA project, the basic emissions model was linked to a series of speed and speed times acceleration look-up tables. The different emission files were subsequently summated to provide overall emissions in terms of grams of pollutant per vehicle kilometre for each scenario.

Noise assessment is generally based on rolling noise sources generated by tyre/road interaction, particularly at moderate to high speed. For low speeds, the so called propulsion noise sources (combustion, gas flow and mechanical noise) are of major interest. Therefore, the effects of congestion and driver behaviour on traffic noise levels at low speeds should be examined.

For road operators, it is necessary to estimate the potential for reducing environmental impacts which will in the future enable them to meet performance targets, for example for carbon emissions and air quality.
6.2 Cost-benefit analysis (CBA)

6.2.1 Methodology

To quantify the impact assessment, a cost-benefit analysis is carried out. To conduct a cost-benefit assessment of cooperative systems, a number of assumptions and decisions must be made. The costs for the infrastructure elements can be obtained from cost databases, e.g. maintained by the U.S. Department of Transportation (RITA 2008) as well as from Elvik et al. (2009). These include cooperative systems operating and maintenance costs and system investments. Differences in life cycles of different components need to be taken into account. Information on costs in other studies may also be helpful, e.g. SMART2010/0063 estimated costs for infrastructure, communications, in-vehicle equipment etc.

In most cost-benefit analyses, the benefits are mainly dominated by fatality and injury reduction due to fewer accidents. Since the figures used to represent accident costs in cost-benefit analysis vary considerably from country to country, the project eIMPACT recommended unit values that should be adopted, similar to values have been used in prior studies (Assing et al. 2006):

- 1 fatality = 1 000 000 EUR
- 1 injured = 100 000 EUR, as the eIMPACT recommendation did not distinguish between severe or moderate and permanent or curable injuries, the average figure should be lower than 137 000 EUR
- material damage per 1 accident = 5 000 EUR.

There is also a need to standardise the definitions of fatalities and injuries of different levels of severity; for example some countries define severity of injuries on the basis of the situation at the time of the crash, while others define them on the basis of outcomes after the event.

In addition, savings in congestion costs, time costs (see Figure 17) and environmental costs should be considered in the CBA. Unit cost rates are available from the SAFESPOT project, covering travel time (freight and passenger transport), fuel prices, NO\textsubscript{x} equivalent for urban and non-urban roads and CO\textsubscript{2} emission costs. CODIA also provides unit cost rates, some of which are different from those used in SAFESPOT. The difference in unit cost rates is one example of some of the uncertainties and difficulties involved in using the results.

<table>
<thead>
<tr>
<th>Country</th>
<th>Freight (EUR/vehicle-hour)</th>
<th>Passenger, personal cars (EUR/person-hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heavy goods vehicle (&gt;3.5 tn) time cost</td>
<td>Work time cost</td>
</tr>
<tr>
<td>Finland</td>
<td>22.21</td>
<td>27.11</td>
</tr>
<tr>
<td>France</td>
<td>35.35</td>
<td>12.50</td>
</tr>
<tr>
<td>Germany</td>
<td>29.73</td>
<td>32.96</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td>31.17</td>
</tr>
<tr>
<td>Latvia</td>
<td>10.55</td>
<td>5.51</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>38.00</td>
<td>25.93</td>
</tr>
<tr>
<td>Portugal</td>
<td>9.12</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>19.98</td>
<td>45.13</td>
</tr>
<tr>
<td>Average</td>
<td>20.39</td>
<td>25.76</td>
</tr>
</tbody>
</table>

Figure 17 Values for time costs listed in the eIMPACT study (Assing et al. 2006)
### 6.2.2 Examples of cost-benefit analysis results

Projects which have assessed the costs and benefits of cooperative systems include eIMPACT, CODIA, the European eCall project, CVIS, SAFESPOT, SPITS and the VII programme in the USA.

In CODIA, the social cost benefit analysis showed that cooperative speed adaptation and local danger warning were economically viable under the range of assumptions made, although both resulted in increased journey times, and should thus be seen as safety systems rather than being expected to generate wider impacts for traffic. The other two applications for which cost benefit analysis was carried out did not prove to be viable: post-crash warning due to its limited impact on safety, and reversible lane control due to the high cost of deployment compared with the low level of benefit (because it is suitable for only a small part of the European road network, suggesting that it should be considered on a project-by-project basis for dealing with local issues).

In SAFESPOT, assuming penetration rates of between 5% and 10% and 50% of infrastructure equipped for short range communications resulted in benefit: cost ratios less than 1, but further analysis indicated that concentrating the infrastructure investment on accident blackspots would improve the case considerably (SAFESPOT 2010b). The financial analysis for road operators indicated that large scale infrastructure investment of this nature could not be operated economically by either private or public road operators because only drivers with high annual mileage would be willing to pay fees to use the service at a high enough rate to cover the cost of the infrastructure (SAFESPOT 2010b).

An additional feature of the SAFESPOT project was that the cost-benefit analysis provided recommendations on the important question of how deployment should begin: should it start with vehicle-to-vehicle based systems, or vehicle-to-infrastructure based systems? The conclusion was that a combination of both is beneficial from the point of view of safety benefits.

In the European eCall impact assessment study, benefit: cost ratios were estimated for EU-25 in 2020 and 2030, under scenarios with three different levels of policy intervention: ‘do nothing’, voluntary deployment by car manufacturers and member states working under an MoU, and mandatory introduction (Francsics et al 2009). The different levels of policy intervention were assumed to result in different penetration rates for eCall in the vehicle fleet. The cost of in-vehicle units was found to be the most critical factor in assessing the costs. Based on reductions in casualties, congestion and emissions, the cost benefit ratio was greater than one (1.31) by 2030 under the mandatory introduction scenario, but not in the other scenarios.

CVIS carried out an economic validation of each of the scenarios analysed, with the aim of identifying how the behaviour of benefit and cost drivers influences the profitability or otherwise of the business case (CVIS 2010). The analysis showed that most of the benefits would appear on major roads and most would be safety benefits. The majority of the costs
were on motorways and major rural roads, and the potential equipment costs were largely on On-Board Units (OBU) and OBU communications. Of the three scenarios analysed, only the public scenario showed a positive cash flow, and this was largely attributed to reduced speeds.

In the SPITS project, business models were developed and the business case assessed for four cooperative services, of which two were of interest to road operators: cooperative mobility and B-call (breakdown call) (SPITS 2011). A cost-benefit analysis was carried out for The Netherlands at three different stages of development. In the case of cooperative mobility these were: advice to drivers by 2015, interaction with driver by 2020 and autonomous following system by 2040. The business case for cooperative mobility was found to be very positive for scenarios with full or high penetration rates, with most of the benefits “societal benefits” (i.e. increasing road safety, traffic efficiency and reduced environmental impact of traffic). The other main benefit is reduction in loss of business time. B-call (automatic call in event of a breakdown) was found to be commercially viable only when bundled with other services so that the cost of the infrastructure is shared – partly because private cars are now very reliable and partly because broken down vehicles rarely cause traffic congestion.

In the USA the Vehicle–Infrastructure Integration Program assessed the benefits and costs of eleven cooperative systems based on 5.9GHz communications deployed across the USA over a 40 year period to 2049. Assuming a seven year life for roadside equipment (shorter than would be expected in Europe), a conservative estimate of benefits was that accidents and congestion would each be reduced by 1%, resulting in a benefit: cost ratio of 1.6 (US DoT 2008).
Part 3 Summary

7 Main points from the review

This review of the current state of the art in cooperative systems has examined recent projects and activities in cooperative systems around the world. The main points that are of particular concern to road authorities, and relevant to developing a decision support tool on cooperative systems, are summarised here.

7.1 Existing implementations and tests

A small number of cooperative systems exist already. These include:

- private eCall services
- dynamic route guidance
- Smartphone apps providing real time traffic information and other services in return for floating vehicle data, which may include road condition monitoring.

There have however been a much larger number of Field Operational Tests and other tests – for example the CVIS project tested 20 applications. Other projects are now in the process of setting up field trials – for example the European HeERO trials for eCall.

So far, most of the Field Operational Tests have focused on systems based on the concept of an on-board unit in the vehicle. These are either built-in, and therefore have a connection to the vehicle sensors, or are a nomadic aftermarket solution, as in the TeleFOT project. Smartphone applications began to emerge after the launch of most of the completed Field Operational Tests, but are clearly now an important feature on the cooperative systems landscape. Some cooperative systems have specific communication requirements and need to use data from in-vehicle sensors and controllers – for example Adaptive Cruise Control. Other cooperative services can be implemented on different platforms, either with or without adaptation – such as dynamic route guidance, which is now available as a Smartphone application.

The tests carried out to date have been aimed at ensuring that the technical challenges posed by cooperative systems can be overcome and some have identified in qualitative terms the benefits that could be achieved. They do not in general address the question of whether the systems under investigation represent the most effective way to derive these particular benefits. Similarly, projects focusing on benefits and costs have not tended to analyse a range of different approaches to achieving the same objectives. Neither do the projects examined in this review provide guidance on best practice for implementation.

7.2 Feasibility of applications in the short to medium term

The consensus is that systems based on nomadic or after-market devices are likely to be the most feasible in the short to medium term. This is consistent with the recent emergence of smartphone applications.

In the studies examined, no single application stood out as having greater potential in the short term than the others; one study concluded that deploying a range of systems, with different effects, appears to be the way forward for achieving substantial impacts. The overall conclusion from the studies examined is that the following application bundles have the highest priority for road operators:

- Traffic information and recommended itinerary with dynamically updated route guidance (enhanced routing)
- Various forms of hazard detection, avoidance and mitigation.
The main characteristics of services which are most likely to be feasible in the short term are:

- Not time-critical safety services
- Clearly beneficial from the perspective of the user without significant investment in equipment - the cost to users of providing data (e.g. to or from road operators) may not be an issue if this can be accommodated within the mobile data allowance on existing contracts
- Based on convenience and do not require a high level of market penetration before they can operate successfully
- Users have the choice of participating, particularly where they are providing privacy-sensitive data (e.g. location), and the use to which any data is put is made clear to the users

The main characteristics of services which are not likely to be feasible in the short term are that they require:

- Changes to the legal framework
- A high penetration rate
- A combination of factors - such as close integration into the vehicle and vehicle-to-vehicle communications – involving a level of agreement on common protocols and data definitions that are not yet available.

### 7.3 Benefits

Potential benefits for traffic safety, traffic efficiency, reductions in the environmental impact of traffic and shorter journey times have been identified, although the emphasis here is on the word potential; studies which have identified potential benefits note many caveats and even at the level of individual studies there is considerable uncertainty.

Because cooperative systems have not yet reached large scale deployment, studies of the benefits of cooperative systems are based on making a series of assumptions about likely market take-up, degree of market penetration necessary for success, scale of impacts etc. In addition some have assessed benefits for specific countries while others have attempted to assess the benefits across Europe. If the assumptions or the area to which they are applied differ, then the benefits assessed will also differ.

An important factor in the assumptions about benefits in a number of the studies is the degree of government involvement in instigating the service. If road users do not see a benefit in a service then they will not pay for it, but government intervention to mandate services (e.g. through legislation or vehicle type approval) can be used to drive deployment (as in the case of eCall in Europe).

### 7.4 Costs

Information on costs is scarce but the main costs involved in many OBU-based cooperative systems have been identified as the in-vehicle equipment (particularly installation costs if retro-fitting) and the communications to/from the vehicles. This does however depend on the design of the system; for example road charging systems can be designed in such a way that a considerable portion of the costs are in the roadside and back-office infrastructure. Different assumptions and bases for estimates lead to different estimates of costs.

Some of the studies reviewed have found that high deployment costs will mean that systems are only suitable for deployment at specific types of site or ‘blackspots’. Others have concluded that individual services will rarely be economically viable, but that bundling of services with complementary functions will make it possible to achieve viable services.

It is important to note that the cost models previously applied for services based on an OBU may not apply to Smartphone-based services. For example what is known about development costs for in-vehicle equipment will not transfer to developing Smartphone apps,
while Smartphone apps will be financed using business models which are largely untested in the transport market.

7.5 Who benefits?

Two particular bundles of applications were identified as forming the focus in the remainder of this project. These are enhanced routing and hazard detection and avoidance. Their benefits are summarised here.

The ‘Traffic information and recommended itinerary with dynamically updated route guidance (enhanced routing)’ applications are expected to provide the following direct benefits for stakeholders:

- **Road users**
  - Shorter journey times
  - More predictable journey times
  - Improved fuel efficiency
- **Service providers**
  - More accurate traffic information
  - Larger market for services
- **Road authorities**
  - Reduced infrastructure costs (by transferring information and guidance into the vehicle)
  - More efficient use of the road network
  - Reduced data collection costs (by replacing roadside sensor equipment with (extended) floating vehicle data)
- **Governments**
  - Roads meet targets for improved efficiency and reduced environmental impact
  - Improved efficiency of the national economy

The hazard detection, avoidance and mitigation applications are expected to provide the following direct benefits for stakeholders:

- **Road users**
  - Improved safety
- **Service providers**
  - Larger market for services
- **Road authorities**
  - Reduced infrastructure costs (by transferring information and guidance into the vehicle)
  - Reduced data costs (by replacing monitoring infrastructure with floating vehicle data)
- **Governments**
  - Roads meet targets for improved safety

7.6 Road maps and scenarios for implementation

A number of projects have developed road maps and scenarios for implementation, but such road maps have not yet been adopted. There appears to be common agreement that services which inform or advise will come first, followed by those providing warnings, instructions, and finally (real) intervention in the driving task. The work on road maps and scenarios will be examined in more detail in the next stage of this project. Key projects to investigate further are: CVIS, SMART 65 and SAFESPOT.
7.7 Legal issues

Liability, privacy and data protection are issues for deployment of cooperative systems; the specific issues vary between cooperative systems and the scenarios in which they are implemented, the issues will also vary between jurisdictions.

The development of commonly agreed guidelines for cooperative systems covering performance requirements, codes of practice, certification and validation will be important for reducing liability risks. Model contracts, insurance risk sharing pools and alternative dispute resolution may also be used to manage concerns over liability.

Following the principle of privacy by design will help to minimise privacy and data protection issues. In Europe, the Directive setting out minimum standards of data privacy does not specify the conditions under which data processing is permissible; for cooperative systems this means that there is a need to clarify the data flows which are permitted, and the purposes for which different data elements are used. Separation of responsibility for independent vehicle based systems and interactive systems, as well as standardisation and harmonisation of security solutions will help to overcome some of the issues. Validation of security and privacy mechanisms in previous field operational tests and further research on security and privacy issues for the next generation of cooperative systems have also been identified as important for resolving privacy and security issues for cooperative systems.

7.8 Next steps

The findings of this review will be used to inform the development of a decision support tool; this is intended for use by road authorities in considering deployment of cooperative systems to serve the users of their road networks. This tool will be the main output of the COBRA project.

---

11 EU Directive 95/46/EG
8 References


EC (2010), ITS Action Plan, Action Area 4, Specific Action 4.1, Adoption of an open in-vehicle platform architecture for the provision of ITS services and applications, including standard interfaces. European Commission DG MOVE, December 2010

eCall Impact assessment (2009), Impact assessment on the introduction of the eCall service in all new type-approved vehicles in Europe, including liability/legal issues, final report, SMART 2008/55


eSecurity Working Group (2010), Vulnerabilities in Electronics and Communications in Road Transport: Discussion and Recommendations, 2010 (last accessed February 2012)


FESTA (2008), D6.3: FOT requirements, legal aspects planning and development, 2008


Kompfner P (no date). Cooperative ITS for Europe “It’s time for deployment ...” http://www.imobilitynetwork.com/assets/PublicAuthority/PAMeeting/6.-Cooperative-Mobility-Alliance.pdf (last accessed February 2012)

Konstantinopoulou, L., Zwijenberg H., Fuchs, S and Bankosegger, D., Deployment challenges for cooperative systems, COOPERS, CVIS and SAFESPOT projects.


SAFESPOT (2010a), D. 6.4.2 , Analyses of Legal Aspects, 2010


SAFESPOT (2010c), D. 6.4.6 Consolidated recommendations dealing with risks and legal aspects, 2010


SAFESPOT BLADE 2010. Final ranking and selection of service and business model. SAFESPOT BLADE D6.6.3.

SAFESPOT SP6 BLADE 2010. The SAFESPOT deployment programme. SAFESPOT Integrated Project - IST-4-026963-IP Deliverable. SP6 – BLADE – Business models, Legal Aspects and DEployment. D6.7.1 Draft


WP 29 (2006) (the Working Party on the protection of individuals with regard to the processing of personal data). Working document on data protection and privacy implications in eCall initiative, 26 September

Willemsen D, de Kievit M, Faber F, Mak. J.SAFESPOT Deliverable D4.6.4 – Evaluation of accident impact through simulation, 31/05/2010
## 9 Appendix 1: Long list of Cooperative Services

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Impact category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelligent speed adaptation (ISA)</td>
<td>ISA is a system that monitors a vehicle's speed and the speed limit on the road being used and intervenes if the vehicle is detected exceeding the speed limit.</td>
<td>S</td>
</tr>
<tr>
<td>ISA with infrastructure enhancements</td>
<td>Basic ISA with additional features which adapt the vehicle's speed to prevailing traffic, weather and road conditions, as well as the posted speed limit.</td>
<td>S</td>
</tr>
<tr>
<td>In-vehicle signage</td>
<td>A vehicle-infrastructure link is used to give information or a warning to a driver of the content of an upcoming roadside sign. This can be extended to inform drivers about other oncoming features of the road such as chicanes, roundabouts, traffic calming installations and road markings such as segregated cycle lanes or bus lanes. This application is often referred to as Visibility enhancement - giving the driver information about situations beyond or outside the direct line-of-sight.</td>
<td>S</td>
</tr>
<tr>
<td>Road condition warning</td>
<td>This uses vehicles as probes to collect information in real-time about road conditions - accidents, temporary speed reduction zones, hazardous weather conditions, operation of a vehicle's stability control, etc. - for transmission to neighbouring vehicles and the infrastructure operator.</td>
<td>S</td>
</tr>
<tr>
<td>Hazardous location notification (combine with above)</td>
<td>Provides a warning notification about potential hazardous areas when approaching them. These areas statistically have more collisions and incidents, and thus require more attention from the driver. This application would have a particular benefit in dynamic situations such as changing weather conditions.</td>
<td>S</td>
</tr>
</tbody>
</table>
## Name | Description
---|---
Low bridge warning (could be included in in-vehicle signage) | The approaches to an especially low bridge can be protected by installing roadside sensors to measure the vehicle’s height and then sending a warning to a driver via roadside signs, or directly to in-vehicle displays, and activating a red traffic signal to indicate that the offending vehicle needs to stop.

Obstacles on driving surface | Debris on the road surface detected by the infrastructure or other vehicles or by traffic management centres (via cameras). The warning message giving the position of the debris is then delivered to drivers via the cellular network or a close range communication option. In this way drivers can adapt their speed and change lane much further ahead of the obstacle. This application would have particular benefit in low visibility circumstances (e.g. fog, heavy rain, dark etc).

eCall/post crash warning/SOS service (?) | If sensors in the vehicle detect that a collision has occurred, the vehicle can automatically make a telephone call to the emergency services to give the incident location, and provide some information about the vehicle and its location. The system opens voice and data channels so that the emergency call centre can talk to the driver or any passengers if they are conscious. The post crash warning part of the application warns drivers when approaching a crashed car either via a message from the crashed car itself or via a following car that detects a crashed vehicle warning ahead.

Special vehicle tracking | A vehicle requiring specific care (hazardous cargo, etc) communicates critical in-vehicle information to the infrastructure. The infrastructure monitors the special vehicle’s conditions, and deploys intervention protocols in an emergency situation.
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Impact category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous goods route guidance (CVIS use case)</td>
<td>Service which supports a truck driver and fleet operator to transport dangerous goods safely. Sensitive areas are provided by the (local) government to the service provider, which uses this information to guide the trucks. A dangerous goods vehicle wants to start CVIS journey and has to register at a traffic management centre which is routing the vehicle during CVIS trip. The traffic management centre provides route guidance to the dangerous goods vehicle and the vehicle is sending back the information of CVIS position and CVIS status.</td>
<td>S</td>
</tr>
<tr>
<td>Safety recall notice (may be convenience, is it cooperative???)</td>
<td>Normally a manufacturer’s safety recall notice is sent to the postal address of the purchaser. This application sends a message directly and immediately to an affected vehicle.</td>
<td>S</td>
</tr>
<tr>
<td>Work zone warning</td>
<td>Carrying out repairs on a live carriageway usually involves temporary speed limits, lane changes, lane merges and contra flow running which are managed by temporary signs and portable physical barriers to divide lanes. A linked vehicle-infrastructure system offers much more flexibility, enabling faster reconfiguring of the work zone and allows precise alerts and instructions to drivers regarding lane choices, speeds, too-close following of preceding vehicles etc.</td>
<td>S</td>
</tr>
<tr>
<td>Adaptive headlight aiming (should this be in cooperative systems???)</td>
<td>Systems are emerging for using inputs from steering to change the ‘aim’ of headlights for better illumination of bends. A new approach is to take information from the infrastructure on the local topography and combine this with the vehicle’s knowledge of its position and speed for optimal illumination of the roadside.</td>
<td>S</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Impact category</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Intersection collision warning</td>
<td>This is similar to Highway/Railway Intersection Warning. Roadside sensors coupled with in-vehicle position and speed broadcasts are used to monitor traffic approaching dangerous intersections and warn vehicles of approaching cross traffic, via roadside signs or directly to in-vehicle displays. The extreme version of this system is not a warning but overrides the driver and automatically applies the brakes as with Intelligent Speed Adaptation.</td>
<td>S</td>
</tr>
<tr>
<td>Pre-crash sensing</td>
<td>If a lateral/longitudinal collision warning system concludes that a collision is likely, it can prepare the vehicle in several ways: boosting brake system pressure ready for an emergency application, winding in any slack on seat belts, adjusting the pattern of the air-bag triggers to reflect the type of impact expected and the number and weight of passengers, and stiffening or relaxing the front or rear suspension depending on the expected impact.</td>
<td>S</td>
</tr>
<tr>
<td>Curve speed warning</td>
<td>Based on received curve information the safe speed is calculated for the vehicle entering the curve and the driver will be warned if current speed is higher than safe speed. SAF: Information is gathered and delivered with a sufficient anticipation to the driver about the road curvature and the adequate speed to keep in the specific black spot. Conditions that may dynamically change the speed and the trajectory to avoid going off the road (road works, static obstacles) are also tackled.</td>
<td>S</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Impact category</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Wrong way ghost driver warning, including special case of gas station and head-on collision (SMART63)</td>
<td>Many countries report that the number of drivers travelling in the wrong direction has been increasing. Such incidents frequently lead to serious accidents and create insecurity among other travellers. Systems have been designed to detect a driver going on to a road on an exit ramp and then activating flashing red lights in the road as a warning as well as sending messages and instructions to the driver and approaching drivers via roadside signs, or directly to an in-vehicle display.</td>
<td>S</td>
</tr>
<tr>
<td>Intelligent traffic lights</td>
<td>Traffic signals at urban junctions have moved away from fixed time allocations to a system whereby flows are measured over a large area and signal timings are managed to maximise movement and minimise waiting for all users. Intelligent signals take this approach a stage further by linking the infrastructure directly to the vehicles. If the control system receives a message from a vehicle that it is about to ignore a red signal, it can delay giving a green signal to drivers on intersecting roads to maximise safety. Also, with much earlier knowledge of traffic flows approaching junctions, the system can reduce waiting times by adjusting the timings of the green signal phases according to the volume of traffic building up on each road.</td>
<td>E</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Impact category</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Electronic brake lights (cooperative collision warning)</td>
<td>If a vehicle brakes suddenly in an emergency, the vehicle emits a warning signal to all other vehicles in its vicinity, which then warns the drivers of the potential hazard. This application is, again, especially useful in low visibility circumstances (e.g. obstruction in front, fog, heavy rain, dark etc.) This is similar to Cooperative collision warning: Vehicle-to-vehicle communication is used to tell following vehicles of problems or sudden manoeuvres by the lead vehicle so that drivers have more time to take evasive action.</td>
<td>S</td>
</tr>
<tr>
<td>Lane change assistant / blind spot warning / highway merge assistant / overtaking vehicle warning / lateral/longitudinal collision warning</td>
<td>Most vehicles have a ‘blind spot’ behind and to the side of them where an overtaking vehicle is momentarily invisible; in the case of a large truck this space can conceal a car for a short time. This system monitors movements at the rear and alerts the driver to an approaching, overtaking vehicle together with a warning should the driver start to move sideways into the other vehicle’s path. It can also alert the approaching vehicle of the intention of the vehicle in front to change lane or in case of overtaking, it can inform the vehicle being overtaken.</td>
<td>S</td>
</tr>
<tr>
<td>Pedestrian crossing information and Vulnerable road user warning</td>
<td>Pedestrian safety systems can help reduce accidents by alerting drivers that they are approaching a crossing, together with any speed limit changes, then automatically activating in-pavement or overhead lighting to alert drivers that pedestrians are using the crossing. The driver also can be warned of other vulnerable road users in the vicinity such as motorcyclists and cyclists.</td>
<td>S</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Impact category</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Stop sign violation and traffic signal violation warning</td>
<td>These applications both use knowledge of a vehicle’s position and speed, combined with information about the physical infrastructure, to predict whether the vehicle is likely to over-run a stop sign marked on the road or pass through a red traffic signal. A warning can be sent to the driver directly using an in-vehicle display or via roadside signs. The knowledge of a possible contravention can also be used to alert other traffic at the site.</td>
<td>S</td>
</tr>
<tr>
<td>Vehicle breakdown warning</td>
<td>Warns drivers when approaching a broken down vehicle either by the stranded vehicle itself or by a following vehicle that detects a disabled vehicle (e.g., detecting zero velocity).</td>
<td>S</td>
</tr>
<tr>
<td>Slow vehicle warning, rear end collision</td>
<td>Warns drivers to prevent rear-end collisions where there are slow moving vehicles ahead.</td>
<td>S</td>
</tr>
<tr>
<td>Emergency vehicle warning and signal priority (blue wave)</td>
<td>An emergency vehicle can alert other vehicles in its vicinity using vehicle-to-vehicle links and thus clear a path through traffic. By connecting with the infrastructure, emergency vehicles can send a request for priority passage through traffic signals: a “Blue Wave”.</td>
<td>S</td>
</tr>
<tr>
<td>Cross flow turn assistant</td>
<td>A form of cooperative collision warning that helps a left-of-road driver turning right and vice versa.</td>
<td>S</td>
</tr>
<tr>
<td>Highway/railway intersection warning</td>
<td>If a vehicle is regularly notifying the infrastructure of its position then it can be given very early warning that it is going to cross a railway line and, if there is an infrastructure/rail link, it can be also be advised whether it is likely to have probable clear passage or will need to stop and wait.</td>
<td>S</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Impact category</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Dynamic Network Performance information to Travellers, includes several applications listed as separate in SMART63, long list 37-41</td>
<td>Live traffic information data collected from probe vehicles, traffic cameras and loops is transmitted to the vehicle or satellite navigation device. Using this information and the details of the final destination, the system plans the route dynamically. In case of high penetration and in case every equipped vehicle serves as a probe vehicle, the quality and accuracy of the data provided by them can replace any additional data source, like loops and traffic counting.</td>
<td>E</td>
</tr>
<tr>
<td>Eco-driving support</td>
<td>Electronic systems can control engines more effectively than people but overall fuel consumption and emissions still depend on the driver’s right foot. In this system the infrastructure reports upstream traffic and geographic features to the vehicle so that the driver can be recommended a strategy for minimising emissions and fuel consumption without affecting journey time and the engine can be kept in its optimal operational zone.</td>
<td>E</td>
</tr>
<tr>
<td>Adaptive drive train management</td>
<td>Infrastructure informs about road structure ahead (such as slope, curve) and possible dynamic road traffic information (for example, queue warning). The vehicle uses the information to prepare and optimize the power train performance (shift, throttle, brakes...).</td>
<td></td>
</tr>
<tr>
<td>Vehicle noise and emissions warning</td>
<td>This is a modified version of Adaptive Drivetrain Management where instead of advising a driver of strategies to minimise emissions, the infrastructure ‘commands’ the vehicle to comply with specific local regulations.</td>
<td>E</td>
</tr>
<tr>
<td>Traffic jam ahead warning</td>
<td>Warns drivers when approaching the tail end of a traffic jam.</td>
<td>E</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Impact category</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Intelligent ramp metering</td>
<td>Instead of loop detection at ramp meters and on the motorway, V2I communication is used to collect information about the location and speed of the vehicles. This provides a more accurate input for the ramp metering algorithms and allows a more optimal traffic flow entering the motorway.</td>
<td>E</td>
</tr>
<tr>
<td>Automatic access control</td>
<td>Grants access to restricted areas automatically. This also includes Intelligent Truck Parking related service.</td>
<td>E</td>
</tr>
<tr>
<td>Cooperative flexible lane allocation</td>
<td>Considers the flexible allocation of a dedicated lane to some vehicles (e.g. public transport or high occupancy vehicles), which receive permanent or temporary access to the lane.</td>
<td>E</td>
</tr>
<tr>
<td>Green light optimal speed advisory</td>
<td>Drivers receive a recommendation in order to hit the next traffic lights in green phase and to avoid waste acceleration.</td>
<td>E</td>
</tr>
<tr>
<td>Cooperative glare reduction</td>
<td>Enables automatic switching of headlights from high-beam to low-beam when a vehicle approaches an oncoming vehicle.</td>
<td>E</td>
</tr>
<tr>
<td>Traffic control assessment (CVIS)</td>
<td>Service which assesses local traffic strategies based on real time traffic information.</td>
<td>E</td>
</tr>
<tr>
<td>Entertainment services (this includes eco-</td>
<td>The high capacity of third and fourth generation of cellular systems and wireless communications enable the use of high speed internet access. With that a lot of new opportunities and applications can be used.</td>
<td>C</td>
</tr>
<tr>
<td>driving in the CVHS report – maybe drop this)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited access warning</td>
<td>Controls the entrance to an area or road segment where some or most vehicles have limited access. An ITS Roadside Station at the entrance announces its presence and approaching vehicles may validate themselves to seek access.</td>
<td>C</td>
</tr>
</tbody>
</table>
## Fleet management
Communication and data processing for assisted management of vehicle fleets, including vehicle maintenance and vehicle tracking, driver management and transport logistics.

## Cooperative adaptive cruise control
Adaptive Cruise Control monitors the distance to the vehicle in front and slows the host vehicle if it is closing too quickly, maintains a set gap, then automatically restores the set speed when it is safe to do so. Cooperative ACC takes this process a stage further and uses traffic flow reports from the infrastructure plus real-time information from the lead vehicle to maintain a much smaller gap automatically.

## Point of interest / parking notification
Drivers receive notifications informing about local peculiarities.

## Remote diagnostics and just in time notification
A vehicle exchanges information with a vehicle service centre for a remote functional diagnosis.

## Coordinated load management (also environmental)

## B-call
On-board systems automatically notify the relevant authorities and/or breakdown service in the event of a vehicle break down.

## Stolen vehicle alert
The information about a stolen vehicle provided to relevant authorities.
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAYD insurance charging services (RA??)</td>
<td>Reward (or punish) drivers when not driving (or when driving) in traffic-peak regions during traffic peak hours. A system in the car monitors the time and route of the driver and communicates with a central system.</td>
</tr>
<tr>
<td>PHYD insurance and charging services</td>
<td>Reward (or punish) drivers based on their style of driving. A system in the car monitors the driver's style and communicates with a central system. This allows higher risk drivers to be charged appropriately.</td>
</tr>
<tr>
<td>Free flow tolling</td>
<td>Vehicles can pay road-user charges without stopping in two main ways. They may fit a registered on-board device that is interrogated by roadside infrastructure to test for a guaranteed line of credit that leads to an off-line invoice, or they may exchange journey and financial information with the roadside that leads to real-time payment or an invoice.</td>
</tr>
<tr>
<td>Floating car data collection</td>
<td>The vehicle reports its position and speed to a centralised system, providing the raw data for many cooperative applications</td>
</tr>
<tr>
<td>Vehicle data sensors</td>
<td>Apart from location information from floating cars, the vehicle also sends other sensor information (accelerometer, temperature, wheel slip, rain, fog etc) to the infrastructure allowing environmental monitoring, road condition monitoring etc. Provides the raw data for more cooperative services.</td>
</tr>
</tbody>
</table>