Cooperative vehicle highway systems – implications for the Highways Agency

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PUBLISHED PROJECT REPORT PPR519

Cooperative Vehicle Highway Systems: Implications for the Highways Agency

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Prepared for: Project Record: 646(387)HTRL
Cooperative Vehicle Infrastructure Systems (CVIS)
Client: the Highways Agency, Network Services (Graham Seaton)

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Executive Summary

The capability to exchange information between vehicles and between vehicles and roadside infrastructure in co-operative vehicle systems creates many opportunities for innovation in the way in which the road network is used and managed. This will not only involve the introduction of new technologies, but also changes in the way in which road operators, vehicle manufacturers, service suppliers and other stakeholders work together to provide services for travellers using the road network.

The following definition has been adopted for co-operative vehicle highway systems:

Co-operative vehicle systems communicate and share information dynamically between vehicles or between vehicles and the infrastructure, to give advice or take actions with the objective of improving safety, sustainability, efficiency and comfort to a greater extent than stand-alone systems.

Co-operative vehicle systems offer a range of potential benefits for road operators which can be linked with the Highways Agency’s key objectives for improved safety, economy and sustainability.

This report was written in 2010 and draws on current projects and recent experiences at that time. It provides an overview of the status of developments in co-operative vehicle systems at that time, to assist the Highways Agency in assessing the implications of future deployment of such systems on the road network. The findings are informed by the experience gained while participating in the European CVIS (Co-operative Vehicle Infrastructure Systems) project.

This report also presents an analysis of key applications for the Highways Agency and a discussion of implementation issues.

In addition, a series of recommendations are made to the Highways Agency, which are summarised below.

1) The analysis of co-operative applications suggests that four are likely to have greatest benefit for the HA and are therefore recommended as having highest priority for further research and development to see whether a business case can be established and, if so, identify a business model of operation. These four are:

   - Dynamic network performance information for travellers
   - Eco driving support
   - Intelligent speed adaptation
   - In-vehicle signs

Before instigating any further work, it is recommended that the Highways Agency validate the process which has been used to identify these and confirm that these are the four applications which are the highest priority for HA research and development.

2) Trials of the most promising applications would help to overcome implementation issues and the anticipated European programme of Field Operational Tests should be considered as a possible mechanism for such trials. Various UK sites are available which could be considered for off-road trials including the InnovITS Advance facility, and the Birmingham Box may be suitable for on-road trials. The European Commission is also expected to issue a call for proposals for further work on co-operative systems, so monitoring of future calls is recommended.

3) If the HA wishes to become involved in, and maximise benefits from, developments in co-operative systems, it is also recommended that it should consider: investigating the internal benefits which could arise from co-operative systems (such as a reduction in reliance on fixed monitoring infrastructure); and reviewing the existing HA capabilities in communications and information gathering and exploring how these might be improved to support co-operative systems.
4) The HA should also consider whether to build into its future work programme further exploration of possible business models and the processes that could support cooperative services. These business models may evolve over time as market penetration increases and applications evolve.

5) A UK stakeholder forum is recommended, led either by DfT, the HA or ITS (UK), to study and address the various issues and establish viable business models and working arrangements such as level of service agreements, certification procedures and data protection and control protocols.

6) To support its continuing responsibility for infrastructure, managing the network and providing information to road users, the HA would benefit from more information relating to some technical aspects of co-operative systems which offer potential to contribute to meeting HA objectives. It is recommended that the HA consider gathering further information on technical questions such as:

- What are the functional requirements of in-vehicle equipment?
- What data can be captured from vehicles?
- Which applications could operate using long range communications to a back office?
- What arrangements for licensing are needed to ensure a future for open interoperable services using infrastructure on the road network?

7) Co-operative vehicle systems continue to evolve and this report presents a snapshot of the situation in 2010. It is recommended that the HA continue to monitor and review the outcome of key European projects in this area which are due to be publishing their results during 2010, including CVIS, COOPERS, SAFESPOT, as well as longer term developments in Europe and further afield.

8) In addition, there are a number of key activities in Europe and internationally where Highways Agency involvement is likely to yield distinct benefits both for the UK and HA operations:

- the high level European ITS Advisory Group - to ensure that the HA will be in a position to influence decisions affecting development and implementation of systems which influence or interact with services on the HA network
- review areas of current involvement in standards development – to ensure an appropriate presence in key areas of co-operative systems relevant to HA interests
- the Open Cooperative Mobility Alliance which is being established by ERTICO – to ensure HA is fully informed in terms of international developments
- the CEDR working group on road maps to deployment – to engage in dialogue with other road operators on strategies and the path to implementation
- the various EasyWay activities focusing on co-operative systems including the Cooperative Systems Task Force, the work to develop a code of practice for road operators involved in co-operative vehicle systems, work on security issues, certification procedures and other issues facing road operators.

9) In addition, the HA should at least monitor, if not become involved in, the work of the eSafety Forum and its working groups, particularly the eSafety Intelligent Infrastructure Working Group and the eSafety Security Working Group; draft reports and information on progress are available in meeting papers on the eSafety web site.
Abstract
The capability to exchange information between vehicles and between vehicles and roadside infrastructure in co-operative vehicle systems creates many opportunities for innovation in the way in which the road network is used and managed. This will not only involve the introduction of new technologies, but also in the way in which road operators, vehicle manufacturers, service suppliers and other stakeholders work together to provide services for travellers using the road network, with mutual benefits for all.

This report was written in 2010 and draws on current projects and recent experiences at that time. An overview of the status of developments in co-operative vehicle systems at that time is provided to assist the Highways Agency in assessing the implications of future deployment of such systems on the road network. The findings are informed by the experience gained while participating in the European CVIS (Co-operative Vehicle Infrastructure Systems) project.

The 'state of the art' of co-operative vehicle systems is reviewed, recent projects and developments in Europe, the USA and Japan are summarised and applications are analysed and priorities identified for the Highways Agency. Implementation issues are discussed, and issues for the Highways Agency are summarised. Recommendations are made for further Highways Agency activities to take forward the development of co-operative vehicle systems.

1 Introduction

1.1 Objectives of this report
The capability to exchange information between vehicles and between vehicles and roadside infrastructure in co-operative vehicle systems creates many opportunities for innovation in the way in which the road network is used and managed. This will not only involve the introduction of new technologies, but also changes in the way in which road operators, vehicle manufacturers, service suppliers and other stakeholders work together to provide services for travellers using the road network, with mutual benefits for all.

This report was written in 2010 and draws on current projects and recent experiences at that time. It provides an overview of the status of developments in co-operative vehicle systems at that time, to assist the Highways Agency in assessing the implications of future deployment of such systems on the road network. The findings are informed by the experience gained while participating in the European CVIS (Co-operative Vehicle Infrastructure Systems) project. More specifically, the objectives of this report are to:

- Provide the Highways Agency with an understanding of the range of co-operative vehicle applications which may reach commercial viability in the next 5 - 10 years, their expected impacts, and where they have potential to provide benefits for the Highways Agency,
- Consider both recent and likely future developments in co-operative vehicle systems,
- Consider the implications of the technologies used in these systems for the services and infrastructure which are managed by the Highways Agency,
- Discuss how the applications fit with the Highways Agency’s own vision for road information systems, in particular the Highways Agency’s role and priorities as proposed in the first report on ‘Strategic Plan for the Highways Agency for the development of future ITS services’,
• Discuss wider issues such as convergence of technologies, interoperability, legal aspects and business models.

1.2 Definition and scope of co-operative vehicle systems

For the purpose of this report, the following definition has been adopted for co-operative vehicle highway systems:

Co-operative vehicle systems communicate and share information dynamically between vehicles or between vehicles and the infrastructure, to give advice or take actions with the objective of improving safety, sustainability, efficiency and comfort to a greater extent than stand-alone systems.

The scope includes a wide range of applications. These range from those which warn the driver, to those which potentially take control from the driver in safety-critical situations. It includes information transmitted from Vehicle to Infrastructure (historic/statistical and dynamic) as well as information communicated from Infrastructure to Vehicle (semi-dynamic and dynamic information). The scope also includes some of the services which involve exchanging Vehicle to Vehicle information, namely those which have implications for network operation or management (e.g. weather information, road surface condition, temperature). The road operator can monitor this information as it is transferred between vehicles and use it for operating or managing the network or informing other road users.

The scope excludes vehicle-based systems that use non-dynamic information received from the infrastructure e.g. temporary speed limits. The scope also excludes the Automated Highway; this is a potential development in which the driver is taken out of the loop under some or all normal driving conditions.

1.3 Potential benefits of co-operative vehicle systems for the Highways Agency

Co-operative vehicle systems offer a range of potential benefits for road operators which can be linked with the Highways Agency’s key objectives for improved safety, economy and sustainability.

By providing vehicles and drivers with better information about others in the immediate vicinity, and about the road environment, the driver can make more reliable safety-critical decisions and safety benefits can be achieved. Capacity improvements can also be made by optimising the space between vehicles and harmonising traffic speeds.

Emissions reductions from individual vehicles can be obtained both by providing vehicles with information about the road ahead which can be used to optimise their fuel efficiency, and by reducing congestion as a result of improving road network management; however in the latter case, overall emissions will only be reduced if the improvement in efficiency does not generate additional traffic.

By monitoring data from vehicles on the road network, the road operator obtains higher quality and more extensive real-time information about traffic and (potentially) environmental conditions on the network. This can be used both to manage traffic more dynamically, improving network efficiency and capacity, and when combined with improved opportunities to communicate with vehicles, can improve the quality and range of information services provided to travellers. It may also be possible to reduce the reliance on expensive infrastructure, for example by moving to basic Variable Message Signs conveying minimal information, with more detailed information communicated directly to co-operative vehicles. Using data from vehicles to monitor traffic and road
conditions can also reduce the road operator’s reliance on conventional monitoring infrastructure, achieving more information for less investment.

### 1.4 Development of HA Strategic Plan for ITS

In 2008 the Highways Agency commissioned a study to develop a long term strategy for ITS research covering a 25 year period. The study drew on the knowledge, thoughts and expertise of a selection of key organisations and individuals to identify priority areas for the Highways Agency’s work. The work was presented to the Highways Agency’s Futures Forum in October 2008 and an initial report on the study was completed early in 2009. It is intended that these initial results will be validated within the Highways Agency before developing the work further at a future date.

The report analysed key groups of applications and ‘ITS enablers’. For each of these it identified:
- priority areas for Highways Agency research and development
- the degree of influence which the Highways Agency has on development and deployment in these areas and
- the areas with a high priority for the Highways Agency researchers to engage with those involved in procurement.

The results of the analysis of application areas are summarised in Table 1.1 below. These aims predate the 2010 election, and reflect expectations at the time about potential long-term research trends.

**Table 1.1 Focus Areas for the Highways Agency in Strategic Plan for ITS - Application Groups**

<table>
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<th>Research Priority</th>
<th>Research Role¹</th>
<th>Procurement Consultation</th>
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<td>Road User Charging</td>
<td>High</td>
<td>Mainly seeds</td>
<td>DRAFT</td>
</tr>
<tr>
<td>Speed Management</td>
<td>High</td>
<td>Mainly seeds</td>
<td>Prioritise</td>
</tr>
<tr>
<td>Operations Management</td>
<td>High</td>
<td>Mainly leads</td>
<td>Prioritise</td>
</tr>
<tr>
<td>Informed Traveller</td>
<td>Medium</td>
<td>Mainly monitors</td>
<td>Prioritise</td>
</tr>
<tr>
<td>Lane Configuration</td>
<td>Low</td>
<td>Mainly leads</td>
<td>DRAFT</td>
</tr>
<tr>
<td>Traffic Prioritisation</td>
<td>Low</td>
<td>Mainly seeds</td>
<td>DRAFT</td>
</tr>
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Identifying where co-operative vehicle systems feature in these focus areas helps to establish which systems are likely to be of greatest importance to the Highways Agency. Within the groups of applications analysed, co-operative vehicle systems are involved in:
- two of the application areas identified as having high priority for research (Road User Charging and Speed Management);

¹ The research roles were defined as follows:
- **Monitors** – others lead the activity and the Highways Agency watches the work to understand progress, direction and the impact on the HA’s business
- **Seeds** – others are willing to lead the activity, but the Highways Agency will need to promote and encourage the direction by seeding ideas, funding, knowledge sharing etc.
- **Leads** – the Highways Agency will provide primary leadership of the activity and will take steps to intervene in the market to move the activity in a precise direction according to the Agency’s wishes
• one of the areas where the Highways Agency is seen as having a leading role in research (Lane Configuration);
• and two of those with high priority for the Highways Agency researchers to engage with those involved in procurement (Speed Management and Informed Traveller).

The involvement of co-operative vehicle systems in these application areas identified as having high priority or a key role for the Highways Agency can be summarised as follows:

• Road User Charging – data from the vehicle used to set charges in road tolling (in the near future where applicable) and providing information for more sophisticated access control systems based on road booking or full road charging to manage demand that could conceivably be considered in the distant future
• Speed Management – in-vehicle speed management and electronically coupled platoons, both of which were envisaged for the distant future although subsequent developments indicate that in-vehicle speed management is likely to be available in the near future
• Informed Traveller – smart navigation based on network conditions, weather and environment (envisaged for the near future)
• Lane Configuration – narrow and dynamic lane running, combined with traffic prioritisation (for vehicles in greatest need of efficient and reliable journeys) and speed management, to enable equipped vehicles to use high-throughput carriageways; these applications are envisaged for the (distant) future.

Links with the initial findings of the study on the Strategic Plan for ITS which should be given high priority within the Highways Agency will be discussed in more detail later in this report, in the context of the co-operative vehicle applications identified in Section 4 of this report.

1.5 Structure of this report

This report contains:

• A review of the ‘state of the art’ of co-operative vehicle systems, covering technological and technical developments, European policy and legislation, standards and initiatives aimed at increasing collaboration between the various stakeholders around the world (Section 2)
• A summary of recent projects and developments in co-operative vehicle systems, in Europe, the USA and Japan (Section 3)
• Analysis of key applications for the Highways Agency, describing the method used to identify which co-operative vehicle systems applications are most important for the Highways Agency to become involved in, and summarising the nature of those priority applications, options for implementing them, their benefits, issues for implementation and next steps for the Highways Agency (Section 4)
• Discussion of implementation issues – for the Highways Agency, liability, security and privacy, standards, commercial issues and market penetration, bundling, legacy systems and unequipped vehicles, contracts, business and organisational models are discussed. Key issues for other stakeholders are also identified.
• Summary of issues for the Highways Agency, looking at issues associated with demonstrating benefits, technical aspects, market
penetration and the business case, managing and influencing stakeholders, arrangements to support services and policy issues

- **Recommendations for the Highways Agency.**

The report includes two Appendices:

- Details of key projects
- Identifying key applications for the Highways Agency – the applications analysed, the method used to assess them and the resulting priority scores.
2 State of the Art

2.1 Technologies

Co-operative vehicle systems are a novel approach which emerged in the last decade which can potentially improve efficiency and safety on the roads. 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 co-operative 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. 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 co-operative 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, a new approach has been initiated. 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 in Section 2.7. The potential of this modular approach is enormous as it does not require changing the applications if new communication technologies emerge.

There is one very important requirement of the technological approach of co-operative systems, which is their interoperability. In order to fully exploit all the possibilities in co-operative systems, interoperability must be retained at all levels of development. 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 is fragmented, costs are high, demand is low and the required critical mass of market penetration is difficult to achieve. A range of different types of agreement and arrangement can contribute to achieving interoperability including standards, agreements, common organisational and business models, and legislation. As part of this project TRL has gathered information on interoperability in current European projects (Tindall, 2010); the key points are 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 the Highways Agency, 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 Highways Agency will need to protect its interests in these areas.
2.2 EC ITS Action Plan and ITS Directive

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). The main objectives were to support the development of pan-European services and to help achieve more environmentally friendly, efficient and safer transport. Co-operative 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 co-operative systems:

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

The European Commission’s ITS Action Plan is supported by a Directive (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 (European Commission 2008b). Co-operative vehicle systems have a key role in this framework.

The responsibilities set out under the Directive include:

- Member States are to be 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 to be 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 co-operative 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 which are outside the scope of the systems covered in this report such as Lane Departure Warning and Advanced Emergency Braking. Legislation for eCall, which is a co-operative system within the scope of this report, is also planned; the European Commission could potentially use these methods to require the introduction of other co-operative vehicle systems in future.

In addition, the Directive provides for a high level European ITS Advisory Group with representatives from Member States, local authorities, service providers and other stakeholders. Clearly the HA, as a national road operator, 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 the HA network, for example through membership of the European ITS Advisory Group.

### 2.3 Standards

Standards are a vital aspect of co-operative 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 co-operative 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 co-operative 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, specifications and guidelines to support deployment of co-operative systems across the European Union and report by 2012.

CEN and ETSI² have accepted this Mandate and have agreed a joint work programme. This lists a minimum set of standards necessary for interoperability and other standards and specifications required for co-operative 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 co-operative systems. The following key areas are included:

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

The minimum standards identified cover the following topics:

- General (e.g. Architecture, Common Data Dictionary)
- Testing
- ITS Applications

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² CENELEC declined the Mandate
• ITS Facilities
• ITS Network and Transport
• ITS Access Technologies
• ITS Security
• ITS Management

The work programme will take account of previous and current standardisation activities relevant to co-operative systems. Figure 2.1 summarises how current standards activities contribute to the topics listed above.

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. The work programme also notes that work is envisaged in future to develop further standards beyond this minimum set.

Developing the standards will involve 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 the Highways Agency here and given the influence of this initiative on standards in general, the HA should consider becoming involved and contributing to developments.

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

2.4 Architecture

The European Commission’s ITS Action Plan includes the following proposals for actions on ITS architecture relevant to co-operative systems:

• Support for the wider deployment of an updated multimodal European ITS Framework architecture for intelligent transport systems (target 2010)

• 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 (target 2011).

To fulfil these tasks, the EC-funded E-FRAME project is extending the European ITS Framework Architecture (FRAME) to include co-operative systems. The project is building on the requirements for co-operative systems which have been identified in three key European projects: SAFESPOT, CVIS and COOPERS, and using these requirements to define how the FRAME architecture needs to be modified to include co-operative system applications and services. 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 co-operative systems. E-FRAME is due to be completed by May 2011.
Figure 2.1 Current standards activities relevant to co-operative systems (Evensen K, Fischer H-J, 2010)
2.5 Recent initiatives for joint working

Three recent initiatives are promoting joint working between organisations with an interest in co-operative systems: Co-operation Agreement with the US on Co-operative ITS systems, the PIARC/ FISITA Task Force and a European initiative which is being facilitated by ERTICO.

At the end of 2008, the European Commission and the Department of Transportation in the USA signed an ‘Implementing Agreement’ for co-operation in research on Information and Communication Technologies applications for road transport (European Commission 2008c). The agreement included co-operation in research and development, particularly coordination of initiatives and projects, with co-operative vehicle-to-vehicle and vehicle-to-infrastructure systems specifically listed as an area for co-operation; a Co-operative Vehicle Highway System working group has already been established.

In 2009 the Joint World Road Association (PIARC) - International Federation of Automotive Engineering (FISITA) Joint Task Force (JTF) was set up with the aim of informing road operators and national roads authorities about IntelliDrive3 and Co-operative 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 is looking at:

- Recent developments around the world
- Deployment issues
- Roles and responsibilities
- Common interfaces and open standards
- Legal and regulatory issues.

ERTICO is in the process of instigating a joint European initiative for a group to promote open co-operative ITS systems, applications and services in Europe, known as the Open Cooperative Mobility Alliance. The group would support a common approach to co-operative systems, looking at issues such as operational rules and organisational models, building joint business and implementation models, and overcoming barriers to deployment. The intention is to bring together the various projects and activities relevant to co-operative systems and key stakeholders in government at all levels, road operators, traffic managers, the automotive and ITS industries, mobile network operators, service providers and users. ERTICO will act as a neutral facilitator for the initiative.

While these initiatives are significant, there some senior industry representatives have commented that there is also a need for a global organisation that will take the lead in coordinating developments and involving all of the key stakeholder groups. Possible candidates include the Organisation for Economic Co-operation and Development, the United Nations (as part of its current initiative to reduce road casualties), the International Telecommunications Union, and automotive manufacturers’ associations.

2.6 In-vehicle hardware

The main hardware component of co-operative 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

3 For more details on IntelliDrive, see Appendix A.
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.

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.

It is yet unclear whether co-operative systems will be available only as factory fitted systems into new vehicles or whether retro-fitting to any vehicle type will be an option. Nomadic devices are also a possibility, although due to the complexity of co-operative systems, the requirement to ‘dock’ with existing vehicle systems and the legal and standardisation issues involved, it is more likely that portable devices will emerge in the future, when co-operative systems are an established technology. Whether factory fitted, retro-fitted or nomadic device, the basic interface cannot differ substantially as interoperability is key to the success of co-operative systems.

2.7 Communications

As mentioned in Section 2.1, one of the core elements of co-operative vehicle systems is the availability of communications. There is a variety of technologies available which are suitable for co-operative systems (e.g. cellular system, Dedicated Short Range Communications, 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 co-operative systems, although performance will vary with communications throughput.

Another important aspect of the communication in co-operative 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 and security issues, the latest (version 6) has been chosen in most of the current co-operative research projects. It is possible that custom protocols would better suit the highly mobile ad-hoc networks inherent in co-operative 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 (Bosson 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.
2.8 Infrastructure

Infrastructures are used as the connection point for the internet and traffic management centres. The core technologies used are the same as in vehicles, but the input and output devices differ – for example they may not have a screen and most infrastructures also lack GNSS units, they can also involve additional equipment such as traffic cameras, monitoring loops etc.
3 Recent Projects and Developments

3.1 Overview
There is a wide range of projects, initiatives and other developments which are concerned with co-operative systems, both in Europe and elsewhere. The scope of these various activities is summarised in Figure 3.1.

This section summarises the recent work to develop co-operative systems, assess their costs and benefits and identify issues for deployment, particularly those faced by road operators.

3.2 Projects developing co-operative systems
This section summarises projects related to co-operative systems relevant to HA interests, most of which are currently on-going or have recently finished. Appendix A provides details of some key projects in Europe and the largest projects in the USA and Japan.

There are differences between Europe, the USA and Japan in the approach to support for Co-operative Vehicle Highway System (CVHS) projects. There is strong governmental support in USA and Japan. In Europe there is support from the European Commission (EC) as well as national governments, and the picture is more heterogeneous with many different countries involved. Thus there are more projects in Europe than in the USA and Japan, and more differences between them compared with those in the USA and Japan.

The three most important and relevant European projects are CVIS, COOPERS and SAFESPOT; these are all expected to publish their final reports during the summer of 2010. These are all projects which are partially funded by the EC, with the involvement of dozens of international companies (from automotive and telecommunication sector and universities), most of which have been participating in all three projects at the same time. These projects are very similar; the objectives and even the technology developments overlap with each other. This results in some duplication of effort. The work in Europe is inherently difficult due to the large number of international companies and countries involved in each project. Hence when comparing the results of these EU projects with the overseas counterparts, it is clear that the European projects are less well developed technologically, but most importantly, that there has been less progress in achieving both acceptance of co-operative technologies and support for their deployment.

From the Highways Agency perspective, the CVIS, COOPERS and SAFESPOT projects are equally significant as all of the technologies which they have been working on are designed to work on motorways. The main differences between the projects are the demonstration applications. The applications appear to show varying levels of benefits and costs, with different stakeholders likely to bear the costs of these systems.

There are purely nationally funded projects as well, from which the Dutch government backed ‘SPITS’ project stands out. It has the aim of producing a co-operative system prototype by integrating existing infotainment platforms which are currently commercially available.
Figure 3.1: Summary of co-operative vehicle projects and activities
3.3 Projects assessing costs and benefits

The direct and indirect impacts, costs and benefits of co-operative systems have been assessed in several projects, the most recent of which is the CODIA project (Co-operative Systems Deployment Impact Assessment, Kulmala et al 2008). Five applications were selected for in-depth review by the European Commission; two of these have also been explored in this study (in Section 4): Speed adaptation and Post crash warning. CODIA concluded that both of these applications are viable and socio-economically beneficial systems. CODIA emphasised the importance of standards for the success of both of these systems.

SAFESPOT also carried out socio-economic, market and financial assessment (SAFESPOT 2010a). From the financial analysis for road operators, the project concluded that large-scale infrastructure equipment for the SAFESPOT system could not be operated economically either by private or public road operators; this is because investment recovery costs would require charging users such high fees that the system would only be attractive to drivers with a very high annual mileage.

3.4 The road operator’s perspective on deployment

SAFESPOT has produced some key reports discussing some of the issues faced by road operators. The SAFESPOT report on organisational architecture covered organisational roles for all different types of stakeholder including road operators (Marco S, Manfredi M and Morello E (2010). SAFESPOT also analysed a range of deployment scenarios and carried out detailed research on the road map to deployment of three of these: ‘technology push’, ‘safety as public good’ and ‘extended traffic management’ (SAFESPOT 2010b). One of the main conclusions was that the first applications to be deployed would be those which are less time-critical and can operate on nomadic devices using existing cellular network technologies; 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 specific context of services aimed at improving road safety, these general points are also relevant for other co-operative vehicle systems.

Issues can arise not only from deployment and business cases but from conflicts between policies or a lack of policy development. This aspect was addressed by a CVIS report (Hoose N 2007). The report’s main aim was to raise all the issues which can arise when co-operative systems are deployed and create a debate about them. The report concluded that lack of policy and policy co-ordination can become a significant barrier for deployment of co-operative systems.

The lessons learned from the CVIS, COOPERS and SAFESPOT projects from the Highways Agency point of view are mainly not technological, but related to the deployment of the technology. In Section 5 of this report, the lessons learned and implementation issues are described in more detail. The biggest issue is the lack of business case, which is mainly based on the ‘chicken and egg problem’ of investment and penetration. In Japan and the USA this issue is approached in an interventionist way by the government which takes up the initial cost of the investments. In this way, the penetration rate can reach a critical level, from which business cases can be developed.

In the UK, the Department for Transport commissioned a report on the state of development and future of CVHS; this was subsequently reviewed in 2003. The review included a "broad brush" examination of the business case for CVHS on motorways. It identified how CVHS can enable the Highways Agency to deliver its
long term objectives, and priorities for HA research were also identified. The report concluded that CVHS offer considerable potential, that reliance on existing infrastructure may help to improve the business case (compared with other parts of the network for example) and that CVHS can be achieved through evolution from the Advanced Driver Assistance Systems which are currently being developed.

The EasyWay project is a collaboration of 21 Member States throughout the EU with a budget of €500 million which is focused on Europe-wide deployment of ITS on main TERN (Trans-European Road Network) corridors, with co-operative systems being just part of its remit. It sets clear targets and has identified the key ITS European services areas (Traveller Information, Traffic Management and Freight and Logistic Services). The project has three stages: 2007-2009, 2010-2011 and 2012-2013. The project supports several expert and study groups and one of them, on ICT Infrastructure, is dealing with all aspects of ICT infrastructure related to current and future EasyWay core ITS services, including co-operative systems. A co-operative systems task force has also been established which has the aim to identify and categorise the relevant applications which are sufficiently mature to be developed and tested in pilot studies.

The next step in the development process would be large scale field operational tests (FOT), which help to further validate the technology and assist with the deployment. So far only a few projects in Europe are implementing large scale field operational tests. SimTD (Safe and Intelligent Mobility Test Field Germany) is planning and preparing for field tests between 2008 and 2011; the tests are due to take place in 2012. In Spain an eCallFOT project involving all stakeholders in the service chain is testing the implementation of the eCall flag and cross-border operation with Portugal.

Large scale field operational tests are an important step toward deployment as they give invaluable information not only about technological issues, but also deal with deployment related concerns. In recognition of the importance of large scale FOTs, a worldwide networking platform for FOTs has been established by the European Commission under the 7th Framework Programme. This aims to bring together European and international stakeholders in a strategic networking platform to present results of FOTs, identify and discuss common working items and promote a common approach for FOTs using the methodology developed in the FESTA project.

Public authorities are seen to have a key role in deploying co-operative ITS systems, particularly in planning and managing road side equipment. Significant innovation and research will be needed before procurement can begin. To assist with this, the P3ITS project (Pre-commercial Public Procurement for ITS innovation and deployment) has recently been established. P3ITS will investigate the opportunities for pre-commercial procurement, which while respecting existing legislation, will stimulate innovation and help the process of moving towards market conditions for large scale introduction of co-operative ITS services. The Open Co-operative Mobility Systems Alliance (mentioned in Section 2.5) which is being set up by ERTICO is also proposing to address these issues.
4  Key Applications for the Highways Agency

4.1  Identifying key applications

Experts have proposed many possible co-operative vehicle applications, but only a sub-set of these will be important to the Highways Agency, either in its role managing the inter-urban road network, or in urban areas which have an impact on the inter-urban road network. Within this sub-set of applications that contribute to the Highways Agency objectives, some will have greater priority than others. A method for identifying and then prioritising the applications was developed by TRL and the HA Project Officer, which led to four key applications being selected for more detailed analysis. This method is summarised here and the four key applications are analysed in the remainder of this Section. The detailed results of the analysis are presented in Appendix 2.

Several lists of possible applications were identified from previous work in this area, including the EasyWay Co-operative Systems Deployment study, a paper by ITS expert Eric Sampson (Sampson, 2010), and previous work by the Highways Agency. The applications in each of these lists were reviewed and after considering overlaps and duplication, a single list of 40 candidate applications was derived.

In consultation with the Highways Agency, a set of five assessment criteria was developed; these were used to carry out an initial assessment of the importance of each application to the Highways Agency. In selecting the criteria to use for this project, criteria used in the EasyWay project for short-listing co-operative vehicle applications to be considered for deployment on the Trans-European Road Network (TERN) were compared. Following this comparison, the five assessment criteria selected for this project were:

1. Potential societal benefits. (Overall benefits to society in terms of reduced numbers of accident casualties, reduced delays due to congestion and reduced emissions).
2. Definition of overall business model. (The extent to which barriers to implementation have been overcome and costs and benefits known – which is a proxy for the maturity of the application or service).
3. Potential strength of Highways Agency business case. (The degree to which a business case for Highways Agency involvement in delivery of application/service can potentially be made).
4. Degree of penetration required. (The penetration of equipped vehicles in the fleet required to deliver appreciable benefits, which is a proxy for the likely time frame for delivering the benefits).
5. Highways Agency role in delivery chain. (The degree to which the Highways Agency would be involved in the delivery of the service).

It is important to note that there is an element of overlap between the criterion 1 (societal benefits) and criterion 3 (Highways Agency business case). This provides an element of ‘weighting’ in favour of applications which meet Highways Agency objectives. Another important consideration is the scope of these criteria; they do not include the strength of political pressure to deploy systems even if their potential benefits to society are limited; if such a criterion had been included in the assessment, then eCall, which the European Commission is pushing forward, would have received a ranking of high priority to the Highways Agency.

The TRL project team and the Highways Agency Project Officer independently assigned a score of ‘high’, ‘medium’ or ‘low’ to each of the 40 applications and the relative differences between scores from both parties were reviewed to compare
scoring. The scores were then summed and assigned to three bands, ('high', 'medium' and 'low') with respect to overall priority for the Highways Agency. In general there was a good level of agreement between the project team and the Project Officer, and where differences did appear these were discussed and a consensus view was reached.

The four applications which were ranked as having 'high' priority for the Highways Agency were:

- Dynamic network performance information for travellers
- Eco driving support
- Intelligent Speed Adaptation
- In-vehicle signs.

By comparison, seven applications were categorised in the EasyWay project as having high priority for road operators on the Trans-European Road Network:

- Hazardous location notification
- Traffic jam ahead warning
- Roadworks warning
- Decentralised floating car data
- Traffic information and recommended itinerary
- In-vehicle signage
- Automatic access control/ parking management (including intelligent truck parking).

Several of these were assessed in this study as being of 'medium' priority for the HA, but EasyWay’s ‘Decentralised floating car data’ and ‘Traffic information and recommended itinerary’ applications together comprise what this project has called the ‘Dynamic network performance information for travellers’ application which is identified here as having a high priority for the HA. Thus while there is not an exact match, there is some agreement between priorities identified in the two projects.

The remainder of this section provides further information on each of the four high priority applications for the HA, outlining the issues and the factors that will need to be taken into account in considering whether or how the Highways Agency should be involved in developing them.
4.2 Intelligent Speed Adaptation

Application: Intelligent Speed Adaptation (ISA)

1. Description
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 to be exceeding the speed limit. The intervention can be advisory, (in which case the driver is warned of the excess) or mandatory (with automatic control of the vehicle’s driving systems to reduce speed to the prevailing limit). ISA acquires the local speed information by one or more techniques: matching the known position to an on-board digital map that includes speed limit information; receiving a wireless broadcast from a roadside transponder that notifies speed limits and changes to them; or through feature recognition technology that detects and interprets speed limit signs.

The ‘base case’ considered for assessing the potential benefits of this application is the situation where no service is currently available. However the current generation of satellite navigation systems now provide autonomous speed limit information, using published speed limit data.

2. Options for technology
Involves accurate information on vehicle position, a centralised database of speed limits and according to the level of intervention, the required technology in the vehicle.
Positioning: either a combination of sensors, navigation tools and DGNSS, or a high resolution map database.
Transmission of speed limit data: long distance transmission via the cellular network or Traffic Message Channel or short range communication via roadside infrastructure.

3. Timeline for development
Demonstration systems have been developed, although so far these are not based on co-operative systems. Research suggests technology may be available now; take up depends on drivers’ acceptance and possible liability issues. Likely to be short term.

4. Technical requirements for infrastructure operator
The HA collects, maintains and updates information on speed limits on its network (including temporary speed limits and variable speed limits on managed motorways). The HA also maintains the map, updating it when new roads are built or changes are made to existing roads. The HA disseminates information to service providers.

5. Impact on driver / vehicle behaviour
By affecting the way in which the vehicle is operated, compliance with speed limits can be improved and variability between vehicle speeds is likely to reduce; fuel consumption and emissions will reduce.

6. Benefits for the Highways Agency
A reduction in speed limit violations would result in a reduced number of accidents, improved journey time reliability and better road network capacity; additionally it would result in lower emissions and fuel consumption by vehicles on the road network, with improved air quality and safety.
Application: Intelligent Speed Adaptation (ISA)

7. Costs
The main cost areas are the in-vehicle equipment, roadside transponders (if used) and the database which contains and provides up-to-date and live information about the speed limits.

The cost of the database will be covered by the road operator and the in-vehicle equipment will most likely be paid by the users.

8. Fit with report on Highways Agency Strategic Plan
In-vehicle speed management is seen as a prospect for the distant future. The report identifies speed management in general as being of high priority for HA research, with a HA role in ‘seeding’ the concept of Intelligent Speed Adaptation with manufacturers; speed management is identified as a priority area for HA procurement consultation.

9. Role in EC ITS Action Plan
The Action Plan does not specifically mention ISA, but it could be viewed as being included in priority action 3.1 which is concerned with promotion and deployment of Advanced Driver Assistance Systems and ITS for safety and security. Installation of such systems in new vehicles and if relevant, retrofitting existing vehicles, are seen as a priority action for 2009 – 2014.

10. Business models and implementation issues
The HA would store the data on speed limits. Dissemination could either be by the HA or by private service providers.
The HA would need to transmit dynamic speed limits on managed motorways and controlled motorways.
The HA may be able to trade data with service providers.
Standardised communications would be beneficial.
An international service would involve additional requirements.
Market penetration could be increased by companies attempting to reduce the likelihood of speeding by fleet vehicle drivers.
The service could be justified on the basis of the reduction in speeding fines (particularly for businesses) and safety improvements.

11. Categorisation metrics
• Potential societal benefits: ‘Medium’
• Definition of overall business model: ‘Good’
• Potential strength of Highways Agency business case: ‘Medium’
• Degree of penetration required: ‘Low/ Short Term’
• Highways Agency role in delivery chain: ‘Medium’

12. Next steps for the Highways Agency
• Monitor developments in vehicle technology.
• Engage in dialogue with possible service providers.
• Investigate requirements for assembling or manipulating data on speed limits in a suitable form for dissemination.
• Later on, feasibility study of business model and business case.
4.3 Dynamic network performance information to travellers

Application: Dynamic network performance information to travellers

1. Description
Live traffic information data collected from probe vehicles, traffic cameras and other roadside sensors is transmitted to a central control system. Using this information and the details of the final destination, the central system plans the route dynamically. At the point where fleet penetration is high and every equipped vehicle serves as a probe vehicle (providing live position data), the quality and accuracy of the data provided by them can replace data from sources such as loop detectors and cameras to manage traffic.

2. Options for technology
Involves information on vehicle position, and live traffic data in addition to the vehicle technology. A standard method of transmission of traffic data would be advantageous.
Positioning: a simple GNSS system is adequate.
Transmission of traffic data: long distance transmission via the cellular network or Traffic Message Channel.

3. Timeline for development
Similar systems have been developed and are currently available on the market, but they are not based on co-operative technology. The co-operative technology would add a finer granularity and reliability to the currently available traffic data, by exploiting many similarly equipped probe vehicles. Technology is available now, but take up depends on the price charged for equipping vehicles compared with the perceived benefit to road users. Overall, the deployment of equipment capable of supporting such concepts (including mobile phone technology) is likely to be short to medium term.

4. Technical requirements for infrastructure operator
The HA or a private company collects, maintains and updates information on traffic conditions. The HA disseminates information to service providers.

5. Impact on driver / vehicle behaviour
By affecting the way the driver chooses the route to the destination, this has the potential to reduce the incidence and duration of congestion, resulting in overall reduction in emissions if no additional traffic is generated; traffic may be more evenly distributed on the road network.

6. Benefits for the Highways Agency
Reduced incidence and duration of congestion, improved journey time reliability, with resulting reductions in emissions and fuel consumption by vehicles on the road network, provided that no traffic is generated; improved safety and more evenly distributed traffic. The feature of providing live position information can result in a gradual decrease in reliance on conventional traffic monitoring systems (i.e. loops).

7. Costs
The main cost areas are the in-vehicle equipment and the database which contains, processes and provides up-to-date and live traffic information.

The cost of the database can be covered either by the road operator or a service provider, while the in-vehicle equipment is most likely be paid by the users.
### Application: Dynamic network performance information to travellers

#### 8. Fit with report on Highways Agency Strategic Plan

Travel information that is available pre-trip and en route travel information is seen as highly likely to develop in the near future.

The HA is seen as:
- leading the cataloguing of HA data, investigating how it can be used, and easing its availability via the HA information strategy
- seeding the concept that the HA may be an enabler to commercial operations
- monitoring the development of commercial navigation systems.

#### 9. Role in EC ITS Action Plan

Procedures for provision of EU-wide real time traffic and travel information services (including guaranteed access by private companies to relevant public data) are to be defined by 2010.

Optimisation of the collection and provision of road data is to be completed by 2012.

#### 10. Business models and implementation issues

The HA or a private company would collect and store the data on traffic conditions.

Dissemination could either be by the HA or by private service providers.

The HA may be able to trade data with service providers.

Standardised communications would be beneficial.

An international service (as proposed in the EC Action Plan) would involve additional requirements.

Market penetration could be enhanced by companies attempting to reduce time spent in congestion and/or minimise the journey time inconsistency of their vehicle fleets.

The service could be justified on the basis of the improvement in journey time reliability, reduction in emissions, particularly CO$_2$, and possibly safety improvements via reduced stress for drivers.

### 11. Categorisation metrics

- Potential societal benefits: ‘High’
- Definition of overall business model: ‘Good’
- Potential strength of Highways Agency business case: ‘High’
- Degree of penetration required: ‘Medium/ Medium Term’
- Highways Agency role in delivery chain: ‘Medium’

### 12. Next steps for the Highways Agency

- Monitor developments in cooperative and non-cooperative traffic sensing technology.
- Engage with standardisation organisations in the process of developing the relevant standards.
- Engage in dialogue with possible service providers.
- Later on, feasibility study of business model and business case.
4.4 Ecodriving – co-operative ecodriving support

<table>
<thead>
<tr>
<th>Application: Ecodriving – co-operative ecodriving support</th>
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</thead>
<tbody>
<tr>
<td>1. Description</td>
</tr>
<tr>
<td>Transmission of data on traffic conditions and road features (such as bends, roundabouts and speed limits). Equipped vehicles use this data to improve fuel efficiency and emissions by adapting the vehicle’s mode of operation to suit these conditions using a form of enhanced cruise control and provide more information (about the driving conditions ahead and feedback about the current driving style) to drivers. There could be several delivery mechanisms. The HA application is the delivery to service providers.</td>
</tr>
<tr>
<td>2. Options for technology</td>
</tr>
<tr>
<td>Involves accurate information on vehicle position, a centralised database of road features and transmission of real time and historic traffic data in addition to the vehicle technology. A standard method of transmission of traffic data would be advantageous.</td>
</tr>
<tr>
<td>Positioning: either a combination of sensors, navigation tools and DGNSS, or high resolution map database.</td>
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<tr>
<td>Transmission of traffic data: long distance transmission via the cellular network or Traffic Message Channel.</td>
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<tr>
<td>3. Timeline for development</td>
</tr>
<tr>
<td>Demonstration systems have been developed but further refinement is needed to maximise benefits. Research suggests technology may be available by 2015; take up depends on market for vehicle control technology. Likely to be medium term.</td>
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<td>4. Technical requirements for infrastructure operator</td>
</tr>
<tr>
<td>The HA collects, maintains and updates information on traffic conditions and road features. The HA also maintains the map, updating it when new roads are built or changes are made to existing roads. The HA disseminates information to service providers.</td>
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<tr>
<td>5. Impact on driver / vehicle behaviour</td>
</tr>
<tr>
<td>By affecting the way in which the vehicle is operated, vehicles are likely to improve compliance with speed limits and variability between vehicle speeds is likely to reduce; fuel consumption and emissions will reduce. By encouraging more measured driving, less vehicle maintenance is required and safety is improved.</td>
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<tr>
<td>6. Benefits for the Highways Agency</td>
</tr>
<tr>
<td>Reduced emissions and fuel consumption by vehicles on the road network, improved air quality and safety (through more moderate driving speeds).</td>
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<tr>
<td>7. Costs</td>
</tr>
<tr>
<td>The main cost areas are the in-vehicle equipment and the database which contains up-to-date and live traffic information and road features.</td>
</tr>
<tr>
<td>The cost of the database might be covered either by the road operator or a service provider, while the in-vehicle equipment is most likely to be paid for by the users.</td>
</tr>
<tr>
<td>8. Fit with report on Highways Agency Strategic Plan</td>
</tr>
<tr>
<td>Informed traveller is suggested as a priority application in the report; the report does not suggest an active role for the Highways Agency in vehicle technology applications.</td>
</tr>
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### Application: Ecodriving – co-operative ecodriving support

<table>
<thead>
<tr>
<th>9. Role in EC ITS Action Plan</th>
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<tbody>
<tr>
<td>Procedures for provision of EU-wide real time traffic and travel information services (including guaranteed access by private companies to relevant public data) to be defined by 2010. Optimisation of the collection and provision of road data to be completed by 2012.</td>
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<tr>
<th>10. Business models and implementation issues</th>
</tr>
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<tbody>
<tr>
<td>The HA or a private company would store the data on road features and traffic. Dissemination could either be by the HA or by private service providers. The HA may be able to trade data with service providers. Standardised communications would be beneficial. An international service would involve additional requirements. Market penetration could be enhanced by companies attempting to reduce emissions and carbon footprint of their vehicle fleets. The service could be justified on the basis of the reduction in emissions, particularly CO₂, and possibly safety improvements. Common approach to dissemination of traffic information.</td>
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<thead>
<tr>
<th>11. Categorisation metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Potential societal benefits: ‘Medium’</td>
</tr>
<tr>
<td>• Definition of overall business model: ‘Good’</td>
</tr>
<tr>
<td>• Potential strength of Highways Agency business case: ‘Medium’</td>
</tr>
<tr>
<td>• Degree of penetration required: ‘Low/ Short Term’</td>
</tr>
<tr>
<td>• Highways Agency role in delivery chain: ‘High’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>12. Next steps for the Highways Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Monitor developments in vehicle technology.</td>
</tr>
<tr>
<td>• Engage with standardisation organisations in the process of developing the relevant standards.</td>
</tr>
<tr>
<td>• Engage in dialogue with possible service providers.</td>
</tr>
<tr>
<td>• Investigate requirements for assembling or manipulating data on road features and traffic in a suitable form for dissemination.</td>
</tr>
<tr>
<td>• Later on, feasibility study of business model and business case</td>
</tr>
</tbody>
</table>
### 4.5 In-vehicle signs/ visibility enhancer

**Application:** In-vehicle signs/ visibility enhancer

<table>
<thead>
<tr>
<th>1. Description</th>
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</thead>
<tbody>
<tr>
<td><strong>In-vehicle traffic signs:</strong> 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 <strong>Visibility enhancement</strong> – giving the driver information about situations beyond or outside the direct line-of-sight.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. Options for technology</th>
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</thead>
<tbody>
<tr>
<td>Involves communicating either static or dynamic sign information to vehicles prior to or at the location of the roadside sign and presenting this to drivers</td>
</tr>
</tbody>
</table>

Positioning: If the information is transmitted from the roadside by short range communications then vehicle positioning is not required. If the information is not transmitted from the roadside then GNSS positioning and a high resolution map database are required. Roadside equipment may be needed in areas where poor GNSS reception is identified.

Transmission of traffic sign data: either long distance transmission via the cellular network or short distance from specific roadside infrastructure.

<table>
<thead>
<tr>
<th>3. Timeline for development</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Japanese demonstration project has used RFID (Radio Frequency Identification) tags on the road surface, however vehicles would need to be fitted with an antenna to receive the data contained in the tag. Other roadside transmission systems would require roadside communication infrastructure. It is unlikely there would be a business case to install this in the short to medium term. However, the infrastructure and technology already exists to deliver this via mobile telecommunications and existing devices such as smartphones and navigation systems. Take up would depend on market demand and this could be short term.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. Technical requirements for infrastructure operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>If road side infrastructure is used, its purpose is to transmit information into vehicles. If the infrastructure is provided by the road operator the information would need to be delivered to all road users in a standardised format. If the infrastructure is provided by 3rd parties the format may be non-standard but the underlying data from the road operator would need to be standardised.</td>
</tr>
</tbody>
</table>

The infrastructure operator will need provide traffic sign (and signal) data. Static data could be provided centrally and periodically updated. Dynamic data would need to be provided in real-time either centrally or locally.

<table>
<thead>
<tr>
<th>5. Impact on driver / vehicle behaviour</th>
</tr>
</thead>
<tbody>
<tr>
<td>By presenting road sign information in-vehicle there is a greater chance that this information will be received and acted upon by the driver. This should result in drivers taking greater heed of warnings and improved compliance with regulatory and advisory information, which should in turn lead to reduced accidents and more efficient vehicle flow.</td>
</tr>
</tbody>
</table>
### Application: In-vehicle signs/ visibility enhancer

<table>
<thead>
<tr>
<th>6. Benefits for the Highways Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is a potential to reduce the need for roadside infrastructure (signs and signals and associated gantries and safety fences) which would reduce the capital and revenue costs for the HA. Improved driver compliance with signs and signals would also improve traffic flow and safety.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>The main costs of implementation are the communications infrastructure and the in-vehicle devices. Who bears these costs is dependent on the business model, but it is likely that they will largely be borne by the service providers and users.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>8. Fit with report on Highways Agency Strategic Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle communications are seen as a high priority for HA research in the capacity of seeding development. Providing traffic sign/signal data to service providers aligns with this.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>9. Role in EC ITS Action Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>This service falls within the scope of Action area 4 - integration of the vehicle into the transport infrastructure and in particular action 4.2 - development and evaluation of cooperative systems</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>10. Business models and implementation issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>The HA would provide road sign and signal data (both static and dynamic). Dissemination of road sign/signal data by either HA or service providers. The HA business case is stronger if communications infrastructure already exists, is provided by others or is cheap to deploy. The justification for providing the data is the potential to reduce the need for expensive roadside signs and signals.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>11. Categorisation metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Potential societal benefits: ‘Medium’</td>
</tr>
<tr>
<td>• Definition of overall business model: ‘Medium’</td>
</tr>
<tr>
<td>• Potential strength of Highways Agency business case: ‘High’</td>
</tr>
<tr>
<td>• Degree of penetration required: ‘Medium/ Medium Term’</td>
</tr>
<tr>
<td>• Highways Agency role in delivery chain: ‘High’</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>12. Next steps for the Highways Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Investigate making road sign/signal data available to 3rd parties.</td>
</tr>
<tr>
<td>• Undertake a pilot to inform business case development</td>
</tr>
<tr>
<td>• Engage in dialogue with stakeholders/possible service providers.</td>
</tr>
</tbody>
</table>
5 Implementation

5.1 Overview

The EasyWay Co-operative Systems Task Force has identified some of the key issues facing road operators in deployment of co-operative vehicle systems, and has proposed a series of activities for the EasyWay future work programme to help address these issues (EasyWay, 2010). A White Paper drawn up by the COOPERS, CVIS and SAFESPOT projects on the main non-technical issues for deployment of co-operative systems provides a joint view on how the three projects see these issues (Konstantinopoulou et al, 2010). This section draws on the White Paper and the work in EasyWay, work in SAFESPOT on organisational architecture and deployment (Marco, Manfredi and Morello 2010 and SAFESPOT 2010b), but also discusses other issues which have emerged from discussions with members of other projects and stakeholders. It focuses on implementation issues which have a bearing on road operators.

In addition, the eSafety Intelligent Infrastructure Working Group is currently compiling a report which covers some of these issues from the point of view of road operators; this will provide further insights into the issues in due course.

This section outlines issues which have been identified including liability, security and privacy, standards, commercial, business and organisational models.

5.2 Liability

Deployment of co-operative vehicle systems will depend on reaching an acceptably low level of risk of legal action. There is already a European code of practice for developing and testing Advanced Driver Assistance Systems which ensures that systems and services are designed in a way that minimises risk and this code of practice may also be suitable for co-operative vehicle systems4. However there is a need to develop a code of practice for road operators involved in co-operative systems; Pre-Drive C2X has done some work in this area and EasyWay has proposed work to define such a code of practice for road operators.

Other tools for managing liabilities identified in CVIS include model contracts, insurance, certification and validation, alternative dispute resolution and risk sharing pools; the project drafted a contractual matrix to describe the types of contract which may be appropriate for governing relations between different organisations involved in providing a service.

In COOPERS, which was concerned with real time traffic information, mandatory certified equipment for transmission of information was seen as the most promising approach to limiting liability: the infrastructure operator guarantees that messages will be generated and transmitted correctly, while the supplier limits liability through equipment certification. In SAFESPOT, it was suggested that in the case of safety applications, there may be a need for drivers to accept general terms and conditions as a pre-condition for using roads where these applications are provided; these would be established by the road operator under a regulatory framework.

One approach to minimising risk which is being discussed in the standards arena is for vehicles to have two platforms for co-operative systems, one for the safety-critical applications which is managed by the vehicle manufacturer and the other for other applications. Any communication between the two would be strictly

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4 An outline of the Code of Practice and discussion on implementation in the UK is available in Cotter, Hopkin and Wood, 2006.
controlled so that the safety-critical systems would not be affected by the other applications.

5.3 Security and privacy

Security, particularly in safety-critical systems, needs to be designed into systems and services in which risk of systems (or their communication links) being tampered with is managed. The eSafety Forum Security Working Group is partially addressing this and EasyWay is proposing to identify the issues faced by road operators in particular.

Many users will require a guarantee of privacy or data protection before they will buy or use co-operative vehicle systems. European Directives on privacy and data protection are already in place and co-operative vehicle systems are required to comply with these, but concern among users is likely to remain. A working party, known as the ‘Article 29 Personal Data Protection Working Party’ has been set up in accordance with article 29 of Directive 95/46/EC.

The European Data Protection Supervisor has made three specific recommendations:

- Privacy by design – building in privacy and data protection while designing the architecture, operation and management of services and incorporating security and privacy requirements in standards, best practice and technical specifications
- Clarify responsibilities between organisations for data protection – identify a data controller
- Safeguard the use of location technologies – data controllers should clarify the circumstances in which vehicles are tracked, limit location devices to those that are necessary for the service to operate and ensure that location data is not disclosed to unauthorised recipients.

5.4 Standards

Standardisation is important in delivering interoperability. Without interoperability there will be a fragmented market which will hamper the take up of co-operative systems and slow down fleet penetration. Benefits will not be maximised and costs will not be minimised. Manufacturers and consumers do not want products or services which operate only in one country or one make of vehicle.

The European Commission’s standardisation Mandate has generated a CEN-ETSI joint work programme that will take forward the work on standards, but it is not yet clear exactly how they will progress as there are various options for the focus of standards. As implied in Section 5.2, the automotive industry prefers to have complete control over safety-critical applications, which could mean that there would be two different in-vehicle platforms: one for safety-critical applications and one for ‘infotainment’ type services. Some argue that the focus for standards should be on the interfaces, the communications, and the services which they are expected to deliver, with no other requirement for standardisation, while others argue that standards should be developed to the extent that it should be possible to ‘plug and play’ a range of devices.

Certification procedures will assist in ensuring compatibility between systems and services, as well as ensuring robustness, security and privacy; such procedures will need to be developed for each of the various type of stakeholder involved in

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5 Directives 95/46/EC, 2002/58/EC and 2003/98/EC.
providing services based on co-operative vehicle systems. EasyWay is proposing to specify certification procedures for road operators.

5.5 Commercial issues and market penetration

Deployment of co-operative vehicle systems involves the usual ‘chicken and egg’ problem. There is little benefit in investing in infrastructure if the number of equipped vehicles is small, and there is little benefit in equipping vehicles if there is no investment in infrastructure. Users will not purchase systems unless they can see tangible benefits (perceived as greater than the cost of buying the system) and there is also reluctance on the part of users to accept such systems and be prepared to pay for them while there are concerns about privacy issues. Marketing and publicising the benefits of co-operative services could assist market penetration, but rapid market penetration cannot be assumed, especially if there is only a very limited incentive for road operators (or others) to invest in infrastructure until market penetration is high.

Systems with high fixed costs (requiring significant infrastructure) will require a rapid growth in market penetration if they are to be financially viable. Such systems are likely to be deployed on a longer timeframe compared with applications which can be realised with in-vehicle equipment only. Many applications can be realised by using a number of technical solutions which support different levels of service. Initially, an in-vehicle approach may be the simplest option to offer, possibly using nomadic navigation devices. Only when either roadside infrastructure or wireless communications to a central office is introduced is the full potential of the application realised. An example is the speed limit warning system. An initial ‘non-dynamic’ system may consist of in-vehicle equipment with GPS and a map of speed restrictions across the network. This is only as good as the map data which it uses. With remote communications to a central office for regular updates to speed limits, combined with the option for roadside beacons\(^6\) providing instant changes to the normal speed limit, a truly dynamic speed warning system can be provided. However, the latter would require a lot more investment by a range of new stakeholders, each requiring a business case to proceed. This is difficult, particularly when the least expensive route guidance systems provide static speed limit data as standard.

Organisations (whether public sector or commercial) will need a clear business case before they can commit to investment in co-operative vehicle systems or a philosophical or political commitment to invest anyway. Socio-economic benefits will need to be demonstrated in terms of safety, economy and sustainability, and these will need to be greater than the investment, operational and maintenance costs. COOPERS, CVIS and SAFESPOT concluded that large scale pilots and Field Operational Tests (FOTs) will be needed to provide the evidence for the business case, implying that there is not currently enough evidence for a business case. SAFESPOT also concluded that starting infrastructure-based services with those that only require infrastructure to be located at specific sites (rather than over the entire network) would also help to minimise risks.

CEDR (the Conference of European Directors of Roads) has established an informal working group to prepare road maps for deploying co-operative systems on a strategic level. The aims include reaching a common vision on the importance of co-operative systems for different stakeholders and developing a framework for a strategy for large scale implementation.

\(^6\) Permanent beacons could be used to transmit dynamic speed limit information to vehicles on managed motorways and controlled motorways, while temporary beacons could be placed at roadworks or incidents
5.6 Bundling

CVIS examined costs and benefits and concluded that the expected benefits of stand-alone personal services (such as traffic information, congestion avoidance and dynamic navigation) and of commercial services for freight and fleet operators (such as access control, booking for loading areas and parking) 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, the issues here concern the increasing complexity of the delivery chain involved in supplying services, requiring more complex organisational arrangements and 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, such that each can see a business case for working together. For example, an in-vehicle navigation service provider would benefit from road operator information to improve route planning, while a road operator could use a navigation service provider’s probe vehicle information to help with reducing congestion and managing traffic and road maintenance.

5.7 Legacy systems and unequipped vehicles

As co-operative vehicle systems penetrate the market, a point will be reached (at some point in the future) when the proportion of vehicles which can provide real-time journey information will be large enough for road operators to be able to consider reducing the level of traditional roadside infrastructure such as buried loops. This may initially only be possible on major roads where the traffic volumes remain sufficiently high throughout the 24 hour period. As penetration increases, less major roads can also be considered. Such vehicles also offer the potential to log sudden jolts to the suspension, suggesting that the road surface has deteriorated and needs repair, thus providing more immediate feedback and the opportunity to respond quickly to damaged roads. This could result in substantial reductions in the investment both in infrastructure and in vehicles equipped to monitor the condition of the road network, helping to meet road operators’ targets for reducing the both the capital and on-going costs of their operations.

However, the issue of vehicles that are not equipped with appropriate co-operative systems (unequipped or obsolete) will need to be addressed. A service for such vehicles could be created, which offers a pool of nomadic devices for loan to travellers who wish to use roads which depend on co-operative vehicle systems for their operation. Another approach could be via legislation to stipulating that vehicles would be permitted to use this part of the road network only if they were equipped with the requisite devices.

5.8 Contracts

Road operators such as the Highways Agency use long term contracts to operate and maintain the road network and provide services for its users (such as the National Traffic Control Centre). When tendering for new suppliers, road operators will need to find ways in which new contracts can provide for the evolution of co-operative vehicle systems without either prescribing the nature of the services that will be deployed or hindering their progress.

There may also be a need for road operators to establish licences or contractual arrangements to enable new service providers to collect data or operate on the road network in other ways, without stifling innovation or disrupting arrangements with existing service providers. The requirement for such arrangements could apply in the case of both in-vehicle systems and services using infrastructure-based equipment.
5.9 Business and organisational models

Sustainable business models are needed to enable the various stakeholders involved to work together. The business model adopted will usually depend on the type of organisation supplying a particular service and whether or not users are expected to pay a charge for the service. It is most likely to succeed if all of the links in the delivery chain are rewarded for providing equipment and services that users are prepared to pay for and which support societal objectives such as improving safety.

There is a need for the responsibilities of the various organisations, including road operators, to be clearly defined before systems can be deployed. Some relevant work has been carried out in the E-FRAME project, and the eSafety Forum’s Intelligent Infrastructure working group; work is also on-going in the standardisation work programme. EasyWay is proposing to identify the roles and responsibilities of road operators in particular.

Where several stakeholders need to be involved in supplying a service, all of them need to be committed to a common path to deployment with agreed timescales. The eSafety Forum Intelligent Infrastructure Working Group has done some work on this and the EasyWay road map, and EasyWay partners’ commitment to working towards the road map, along with industry partners, will also help to address this issue. The CEDR working group on road maps for deployment of co-operative systems aims to identify business models covering the interests of all strategic stakeholders. The Open Co-operative Mobility Systems Alliance which is being instigated by ERTICO, and some of the other initiatives for joint working mentioned in Section 2.5 could provide the platform for working together on a common path to deployment.

CVIS, SAFESPOT and COOPERS concluded that to ensure that infrastructure operators could commit to investing, private partnerships would need to be established.

In addition to organisational models, agreements between the various organisations involved are also needed on service quality to ensure that minimum levels of service are met.

The large scale operational trials proposed by COOPERS SAFESPOT and CVIS will not only help to validate the business case (as suggested earlier) but will also enable organisational and business models to be tested and appropriate service quality levels to be established, prior to full scale deployment.

5.10 Summary of issues for other stakeholders

Many of the issues discussed earlier affect many of the stakeholders involved. Some of the key issues identified are listed in Table 5.1. Further discussion of the issues facing policy-makers at international and national level and in transport authorities and network operations are available in one of the CVHS reports (Hoose 2007).
### Table 5.1 Summary of key issues for other stakeholders

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Issue/ Risk</th>
<th>Possible Action/ mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>All stakeholders</td>
<td>Reaching a critical mass of equipped vehicles for communication between vehicles</td>
<td>Using nomadic navigation devices as a 'launch pad' to encourage market penetration</td>
</tr>
<tr>
<td>All stakeholders</td>
<td>Commercial risk and lack of business case</td>
<td>Work towards deployment in small steps, preceded by field trials</td>
</tr>
<tr>
<td>All stakeholders</td>
<td>In-vehicle systems do not collect all of the data that is needed to support a full range of services to meet all stakeholders’ needs</td>
<td>Stakeholder forum – bringing together equipment manufacturers, service providers and road operators to agree on functionality</td>
</tr>
<tr>
<td>Policy makers</td>
<td>Inclusivity – reluctance to pay for infrastructure that will only benefit drivers who can afford equipped vehicles so publicly funded investment in infrastructure might only occur when mass market vehicles are equipped</td>
<td>Loan of nomadic devices for unequipped vehicles</td>
</tr>
<tr>
<td>Policy makers</td>
<td>Liability, security and violations</td>
<td>Establish technology standards, enforcement strategies and means of guaranteeing safe and secure use of the systems</td>
</tr>
<tr>
<td>Vehicle manufacturers</td>
<td>Integrity of safety-critical systems</td>
<td>Two in-vehicle platforms - one for safety critical systems, managed by manufacturers – with standards for interfaces and communications between them</td>
</tr>
<tr>
<td>Vehicle manufacturers</td>
<td>Risk of monopoly suppliers</td>
<td>Develop standards for interface to the engine management system and the in-car sensors so that an open market for nomadic devices can operate</td>
</tr>
<tr>
<td>Existing service providers</td>
<td>Current commercial arrangements could be undermined</td>
<td>Negotiations for data sharing to improve services for both road operators and service providers – mutual benefit</td>
</tr>
<tr>
<td>Communications providers</td>
<td>Overloading the network</td>
<td>Asymmetric communications broadcast message with local filtering by individual vehicles</td>
</tr>
<tr>
<td>Users</td>
<td>Guaranteed privacy and data protection</td>
<td>Design, clear responsibilities and secure data</td>
</tr>
<tr>
<td>Users</td>
<td>Requirement for vehicles using specific roads to be equipped</td>
<td>Loan of nomadic devices for unequipped vehicles</td>
</tr>
</tbody>
</table>
6 Summary of Issues for the Highways Agency

6.1 Demonstrating benefits

Co-operative systems can assist the HA in pursuing its long term objectives. The HA has, in any case, a key role in deployment of both co-operative and non co-operative systems, particularly in planning and managing roadside equipment. In terms of specific investment in co-operative systems, a socio-economic benefit case will generally need to be demonstrated, unless there is political will to invest in such systems anyway.

6.2 Technical issues

Interoperability is a key factor for the success of co-operative vehicle systems. The HA is likely to have a continuing responsibility both for infrastructure and providing information to road users, so will wish to protect its interests in interoperability, particularly where this affects roadside infrastructure, gathering probe vehicle data and delivering information to vehicles. The impact of co-operative systems on the interface between systems which manage urban and inter-urban traffic will also need to be considered, particularly in the context of UTMC (Urban Traffic Management and Control) coordination.

The functional requirements of any in-vehicle equipment installed by manufacturers will have an influence on the data that is available from vehicles for many years to come. Bearing in mind the potential for probe vehicle data to enhance and eventually replace current traffic and road condition monitoring systems, it would be beneficial for the HA to establish what in-vehicle equipment is needed to provide the most effective probe data so that these benefits can be maximised. Examples include accelerometers to detect sudden changes of speed and bumps in the road surface, and whether the HA would benefit from more accurate position data (lane accuracy or road accuracy) than is already obtained by current navigation systems.

Similarly, it would be advantageous for the HA to establish what data can be captured from vehicles to manage HA operations and how this can best be collected.

Experience of the evolution of other ITS services suggests that standards and technological developments will resolve the technical issues in due course. A range of other issues have also been identified, which are summarised in the following paragraphs.

6.3 Market penetration and the business case

A key barrier to deployment is that there is little benefit in investing in infrastructure while there are few equipped vehicles, but there is little benefit in equipping vehicles if there is no investment in infrastructure. Some co-operative systems can evolve from existing systems and initially use existing infrastructure to improve the business case. Further evidence is needed on the business case for the most promising applications for the HA, and how it is affected by different levels of penetration and market development.

Some applications will not need roadside infrastructure, because vehicles will be able to use cellular networks to communicate with a back office. This clearly requires substantially less infrastructure investment than systems which are based on roadside equipment. It would therefore be advantageous for the HA to identify which of the applications supporting HA objectives can work with long distance communications to a back office and whether a business case for them
can be established; these may be suitable candidates for initial investment in co-operative systems.

6.4 Managing and influencing stakeholders

The delivery chain for co-operative systems is complex. Mechanisms will need to be found for: managing the range of different types of stakeholder involved in delivering co-operative systems (probably via a series of ad hoc alliances); ensuring that there is a business case for them to work together; and resolving the associated architecture issues to ensure that systems are inter-operable and support the entire service delivery chain. A possible model may be an arrangement similar to the one established for the Traveller Information Highway, covering Value Added Service Providers and operators of different networks. CVIS has done some preparatory work in this area, but there is a need to determine who in the UK should take the lead in this process.

A forum for UK stakeholders, led by the HA or the Department for Transport, would provide a mechanism for working together to resolve issues. This could involve national and local authorities, mobile network operators, manufacturers and service suppliers.

To maximise the potential of in-vehicle equipment to provide information for the HA, the HA will need to be able to influence manufacturers, either directly or through the standardisation process.

6.5 Arrangements to support co-operative services

Under the European Commission’s ITS Directive, Member States are responsible for ensuring coordinated deployment of interoperable services. The Highways Agency has a role in key areas such as making up-to-date data available, ensuring that traffic and travel information can be exchanged between traffic and travel information centres and integrating applications involving exchange of information between vehicles and infrastructure.

It is unrealistic to expect that competing organisations will be willing to share data, but bi-lateral arrangements between the HA or DfT and specific organisations would enable data to be exchanged (under suitable agreements covering confidentiality, Intellectual Property, how the data is used, etc.) for mutual benefit of both parties.

Arrangements for contracts, level of service agreements, certification and other mechanisms for risk sharing would also need to be established. The long term nature of some of the HA contracts will mean that contracts for providing services on the HA network will need to provide for evolution of co-operative systems.

Data protection and control arrangements and responsibilities also need to be established.

Licensing can be another barrier to deployment. If not already known, the HA may also need to establish what powers are available for granting licences to organisations for installing equipment on the HA network and the implications of those powers for possible future arrangements to provide services on the network.

6.6 Policy issues

As mentioned in Section 3.4, research in CVIS has shown that lack of policy and lack of policy coordination can be a significant barrier to deployment of co-operative systems. The HA and DfT have a role to play in driving policy formation.
An issue for the (possibly) more distant future concerns public duty to road users and equity. If co-operative vehicle systems penetrate the market to the extent that road operators can reduce the level of service provided via roadside signs, the question of how non-equipped vehicles should be dealt with will arise. Should these be provided for in other ways (e.g. by providing a pool of nomadic devices for hire before using the equipped roads), should the HA continue to provide a service for the diminishing minority, or should non-equipped vehicles be banned from using such routes?
7 Recommendations

1) The analysis of co-operative applications (Section 4) suggests that four are likely to have greatest benefit for the HA and are therefore recommended as having highest priority for further research and development to see whether a business case can be established and, if so, identify a business model of operation. These four are:

- Dynamic network performance information for travellers
- Eco driving support
- Intelligent speed adaptation
- In-vehicle signs and visibility enhancer

Before instigating further work, the Highways Agency should validate the process which has been used to identify these and confirm that these are indeed the four applications which are the highest priority for HA research and development.

2) Trials of the most promising applications would help to overcome implementation issues and the anticipated European programme of Field Operational Tests should be considered as a possible mechanism for such trials. Various UK sites are available which could be considered for off-road trials including the InnoVITS Advance facility, and the Birmingham Box may be suitable for on-road trials. The European Commission is also expected to issue a call for proposals for further work on co-operative systems, so monitoring of future calls is recommended.

3) If the HA wishes to become involved in, and maximise benefits from, developments in co-operative systems, it is also recommended that it should consider: investigating the internal benefits which could arise from co-operative systems (such as a reduction in reliance on fixed monitoring infrastructure); and reviewing the existing HA capabilities in communications and information gathering and, how these might be improved to support co-operative systems.

4) The HA should also consider whether to build into its future work programme further exploration of possible business models and the processes that could support co-operative services. These business models may evolve over time as market penetration increases and applications evolve.

The following approach is suggested, for defining the business and organisational models, understanding the chain of liability and the risks and interdependencies that are created:

1. Identify primary (delivery) activities and roles
2. Identify barriers to delivery and corresponding enabling activities
3. Identify enabling roles
4. Identify costs and benefits for each role
5. Identify possible development scenarios and associated development stages leading to the final operational (delivery) stage
6. For each phase of each scenario show the relationships between the primary and enabling roles in terms of exchange of costs and benefits to create ‘profit’ within the value chain. This will enable the relationships to be defined on a two-way basis involving financial transactions.

5) A UK stakeholder forum is recommended, led either by DfT, the HA or ITS (UK), to study and address the various issues and establish viable business models and working arrangements such as level of service agreements, certification procedures and data protection and control protocols.
6) To support its continuing responsibility for infrastructure, managing the network and providing information to road users, there are some technical aspects where the HA would benefit from having more information about co-operative systems which offer considerable potential to contribute to meeting HA objectives. It is recommended that the HA consider gathering further information on technical questions such as:

- What are the functional requirements of in-vehicle equipment?
- What data can be captured from vehicles?
- Which applications could operate using long range communications to a back office?
- What arrangements for licensing are needed to ensure a future for open interoperable services using infrastructure on the road network?

7) Co-operative vehicle systems continue to evolve and this report presents a snapshot of the situation in 2010. It is recommended that the HA should continue to monitor and review the outcome of key European projects in this area which are due to be publishing their results during 2010, including CVIS, COOPERS, SAFESPO7, as well as longer term developments in Europe and further afield.

8) In addition, there are a number of key activities in Europe and internationally where Highways Agency involvement is likely to yield distinct benefits for the UK and HA operations:

- the high level European ITS Advisory Group - to ensure that the HA will be in a position to influence decisions affecting development and implementation of systems which influence or interact with services on the HA network
- review areas of current involvement in standards development – to ensure an appropriate presence in key areas of co-operative systems relevant to HA interests
- the Open Cooperative Mobility Alliance which is being established by ERTICO – to ensure HA is fully informed in terms of international developments
- the CEDR working group on road maps to deployment – to engage in dialogue with other road operators on strategies and the path to implementation
- the various EasyWay activities focusing on co-operative systems including the Cooperative Systems Task Force, the work to develop a code of practice for road operators involved in co-operative vehicle systems, work on security issues, certification procedures and other issues facing road operators.

9) In addition, the HA should at least monitor, if not become involved in, the work of the eSafety Forum and its working groups, particularly the eSafety Intelligent Infrastructure Working Group and the eSafety Security Working Group; draft reports and information on progress are available in meeting papers on the eSafety web site.

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7 The expected completion dates of the key projects are listed in Appendix A.
Acknowledgements

The work described in this report was carried out in the ITS Group of the Transport Research Laboratory. The authors are grateful to Alan Stevens who carried out the technical review and auditing of this report, and to Graham Seaton, the Highways Agency Project Officer.

References


SAFESPOt Project (2010b). *The SAFESPOt Deployment Programme.* D6.7.1. SAFESPOt project.


## Glossary of Terms and Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>CALM</td>
<td>Communications Architecture for Land Mobiles, also known as Communications Access for Land Mobiles</td>
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<tr>
<td>CEN</td>
<td>Comité Européen de Normalisation): European Committee for Standardisation</td>
</tr>
<tr>
<td>CENELEC</td>
<td>Comité Européen de Normalisation Electrotechnique): European Committee for Electro-technical Standardisation</td>
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<tr>
<td>CEDR</td>
<td>Conference of European Directors of Roads</td>
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<tr>
<td>CODIA</td>
<td>Co-operative Systems Deployment Impact Assessment project</td>
</tr>
<tr>
<td>COOPERS</td>
<td>CO-OPERative systems for intelligent Road Safety project</td>
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<tr>
<td>CVIS</td>
<td>Co-operative Vehicle Infrastructure Systems project</td>
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<tr>
<td>CVHS</td>
<td>Co-operative Vehicle Highway Systems</td>
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<tr>
<td>DfT</td>
<td>Department for Transport</td>
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<tr>
<td>E-FRAME</td>
<td>European project to extend the European Framework Architecture to co-operative systems</td>
</tr>
<tr>
<td>ERTICO</td>
<td>Multi-sector public private partnership to develop and deploy ITS in Europe</td>
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<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
</tr>
<tr>
<td>FISITA</td>
<td>International Federation of Automotive Engineering</td>
</tr>
<tr>
<td>FOT</td>
<td>Field Operational Test</td>
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<tr>
<td>FP6</td>
<td>European Commission 6th Framework Research and Development Programme</td>
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<tr>
<td>FP7</td>
<td>European Commission 7th Framework Research and Development Programme</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>HA</td>
<td>Highways Agency</td>
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<td>ISO</td>
<td>International Standards Organisation</td>
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<td>ICT</td>
<td>Information and Communications Technologies</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>ISA</td>
<td>Intelligent Speed Adaptation</td>
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<td>IT</td>
<td>Information Technology</td>
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<td>ITS</td>
<td>Intelligent Transport Systems</td>
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<td>P3ITS</td>
<td>Pre-commercial Public Procurement for ITS innovation and deployment project</td>
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<tr>
<td>PIARC</td>
<td>World Road Association</td>
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<tr>
<td>SAFESPOT</td>
<td>Project to develop a “safety margin assistant” to extend driver awareness</td>
</tr>
<tr>
<td>SPITS</td>
<td>Dutch project to develop prototype platform for co-operative systems</td>
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<tr>
<td>TERN</td>
<td>Trans-European Road Network</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<td>---------</td>
<td>-----------------------------------</td>
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<tr>
<td>UTMC</td>
<td>Urban Traffic Management and Control</td>
</tr>
<tr>
<td>V2V</td>
<td>Vehicle-to-Vehicle communications</td>
</tr>
<tr>
<td>V2I</td>
<td>Vehicle-to-Infrastructure communications</td>
</tr>
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Appendix A  Key Projects

This appendix provides a summary of the scope of key projects in Europe, the USA and Japan.

A.1 European Projects

**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 in regard vehicle-to-infrastructure (V2I) communication. Its goal was to enhance road safety by providing faster and real time information exchange to drivers related to traffic, weather and road infrastructure etc.

The COOPERS system was tested and validated on public roads in France, Belgium, Netherland, Germany, Austria and Italy.

**CVIS**

Co-operative Vehicle Infrastructure Systems was also part of the EC FP6 programme and started in 2006 with 60 partners. 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 is not only on safety related issues, but other convenience-oriented applications (i.e. parking management) were developed as well.

CVIS was tested in seven European countries: Belgium, France, Germany, Italy, Netherland, Sweden, and the United Kingdom.

**SAFESPOT**

SAFESPOT is another example of an EC FP6 programme which started in 2006. 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.

**SeVeCOM**

Secure Vehicular Communication, an EC FP6 project which started in 2006, had 8 partners, with the goal of defining the security architecture of V2V and V2I networks and proposing a roadmap for integration of security functions in these networks. The project is now complete.
**SPITS**

The SPITS project’s objective is 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 Dutch organisations. The end result of the project in 2011 will be a scalable and upgradable prototype.

**GeoNet**

GeoNet – Geographic addressing and routing for vehicular communication was an EC FP7 project which started in 2008. 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.

**Pre-Drive C2X**

PRE-DRIVE C2X was an EC FP7 project which started in 2008. 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 framework of a field operational test.

**Expected completion dates for key European projects**

To assist the HA in monitoring the outcome of current European projects, the list below indicates the expected completion dates for the key projects.

- COOPERS – 31/01/2010
- CVIS – 30/06/2010
- EASYWAY – 2013
- GEONET – 31/01/2010
- PREDRIVE C2X – 30/06/2010
- SPITS – 31/07/2011
- SAFESPOT – 31/01/2010
- SEVECOM – 31/12/2008
A.2 Overseas Projects

IntelliDrive (USA)

IntelliDrive (formerly known as Vehicle Infrastructure Integration (VII)) started in 2005, combines leading edge technologies providing the capability for vehicles to identify threats and hazards on the roadway and communicate this information over wireless networks to give drivers alerts and warnings.

At IntelliDrive’s core is a networked environment supporting very high speed transactions among vehicles (V2V) and between vehicles and infrastructure components (V2I) or hand held devices (V2D) to enable numerous safety and mobility applications.

The system identifies, collects, processes, exchanges, and transmits real-time data to improve the driver’s awareness of the surroundings. IntelliDrive provides the vehicle with the ability to respond and react, when the driver cannot or does not react in time, significantly increasing the effectiveness of crash prevention and mitigation applications.

The Consortium (30 members) consists of the U.S. Department of Transportation, light vehicle manufacturers, state and local governments, and their representative associations. They also work with other sectors and industry experts on specific aspects of IntelliDrive, such as applications development.

ASV (Japan)

The goal of Advanced Safety Vehicle (ASV) is to drastically reduce accidents caused by driver error. Important aspects are:

Development of inter-vehicle communication which includes “vehicle intelligence”.
Introductory of some inter-vehicle communication (V2V) type driver assistance systems.
Inter-vehicle communication will provide support when onboard sensors are not sufficient.
This project consists of four phases. Phase 1-3 was finished by 2005 and currently phase 4 is in progress, which will finish in 2010. One of the goals in this phase is to introduce full-scale autonomous detection type driver assistance systems and some inter-vehicle communication solutions.

This project is promoted by the Road Transport Bureau of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT).
Appendix B  Identifying Key Applications for the Highways Agency

B.1 Overview
This Appendix describes the 40 co-operative vehicle systems which were analysed to identify the four key applications for the Highways Agency which were presented in Section 4. The results of this analysis are then presented in a table which shows how each of the 40 applications scored on the factors used to identify priorities.

B.2 Summary of applications
1) Dynamic network performance information to travellers: 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.

2) Intelligent speed adaptation [ISA]: 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. The intervention can be advisory where the driver is warned of the excess, or mandatory with automatic control of the driving systems of the vehicle to reduce speed to the prevailing limit. ISA acquires the local speed information by one or more techniques: matching the known position to an on-board digital map that includes speed limit information; receiving a wireless broadcast from a roadside transponder that notifies speed limits and changes to them; or through feature recognition technology that detects and interprets speed limit signs.

3) Eco-driving support: 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.

4) In-vehicle traffic signs: 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.

5) Traffic jam ahead warning: In the event of a traffic jam, the infrastructure or the vehicles already stuck in the jam send warning signals to vehicles following them, which helps them to slow down in time. This application is especially useful in low visibility circumstances (e.g. fog, heavy rain, dark etc.). It potentially reduces the need for queue protection infrastructure (MIDAS) which is currently deployed on 50% of the motorway network and hence could potentially provide significant cost reductions for the HA.

6) Intelligent on ramp metering: 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. At the point when penetration is high and 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.

7) **Road condition warning:** This system 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.

8) **Hazardous location notification:** This 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.

9) **Low bridge warning:** 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.

10) **Obstacle 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).

11) **eCall/Post-crash warning:** 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.

12) **Entertainment services:** 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, such as:

- Download of multimedia content (audio, video) for entertainment
- Download of maps and map updates from map servers
- Techniques focusing on safe, environment-friendly and economic driving style and behaviour
- Vehicle-to-vehicle instant messaging service (also known as chat system).
- Exchange of personal data for synchronisation between the devices in the vehicle and components at home, e.g. a personal computer.

13) **Safety recall notice:** 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.

14) **Limited access warning and automatic access control and intelligent truck parking:** 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.

15) **Cooperative flexible lane allocation**: 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.

16) **Fleet management**: Communication and data processing for assisted management of vehicle fleets, including vehicle maintenance and vehicle tracking, driver management and transport logistics.

17) **Non-stop tolling**: 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. A similar approach is used in the *Pay/earn as you drive* application, which rewards (or penalises) drivers when not driving (or when driving) in traffic-peak regions during traffic peak hours. A system in the car controls the time and route of the driver and communicates with a (de)central system.

18) **Work zone warning**: 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.

19) **Cooperative adaptive cruise control**: Simple cruise control enables a speed to be set which a vehicle will keep automatically. 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.

20) **Adaptive headlight aiming**: 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.

21) **Intersection collision warning**: 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.

22) **Point of interest/Parking notification**: Once the infrastructure learns the location of a vehicle and the expected arrival time, site-specific information can sent to a driver via roadside signs, or directly to in-vehicle displays. The information can be related to local businesses and services, local point of interests etc.

23) **Pre-crash sensing**: 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.

24) Remote diagnosis and just in time notification: A vehicle exchanges information with a vehicle service centre for a remote functional diagnosis.

25) Green light optimal speed advisory: Drivers receive a recommendation in order to hit the next traffic lights in green phase and to avoid wasted acceleration.

26) Curve speed warning: Where there is a very tight bend on a road, the infrastructure can measure an approaching vehicle’s speed and send a warning message directly to the driver and/or trigger a roadside message display. Alternatively the vehicle can broadcast its speed to the infrastructure and be ready to receive an excess speed warning.

27) Wrong-way (ghost) driver warning: 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.

28) Intelligent traffic lights: 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.

29) Blind merge warning: The physical layout of many grade-separated intersections with space restrictions often requires sharply curving lanes for merging, with poor sight-lines for drivers. Systems are being trialled that monitor vehicles’ movements and present messages at the roadside or inside a vehicle informing and warning of the presence of another unseen vehicle.

30) Electronic brake lights: 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.

31) Lane change assistant/Blind spot warning and Highway merge assistant and Overtaking vehicle warning and Lateral/longitudinal collision warning: 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.

32) **Vehicle noise & Emissions limiting:** 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.

33) **Pedestrian crossing information and Vulnerable road user warning:** 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.

In CVIS an application has been developed in which the vehicle, on detecting unpredictable driver behaviour, informs the intelligent intersection. Both driver and pedestrian are warned either through the HMI displays in the vehicle or on a mobile phone, or by altering traffic light phases. The driver behaviour is compared to reference models implemented using a ‘potential field’ approach.

34) **Stop sign violation warning and Traffic signal violation warning:** 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.

35) **Vehicle breakdown warning:** 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).

36) **Slow vehicle warning:** Warns drivers to prevent rear-end collisions where there are slow moving vehicles ahead.

37) **Emergency vehicle warning and Signal priority:** 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 “Green Wave”.

38) **Cross-flow turn assistant:** A form of co-operative collision warning that helps a left-of-road driver turning right and vice versa.

39) **Highway/Railway intersection warning:** 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.

40) **Co-operative glare reduction:** Enables automatic switching of headlights from high-beam to low-beam when a vehicle approaches an oncoming vehicle.

### B.3 Prioritising the applications

If co-operative systems are widely installed in vehicles and infrastructure is available, than all the listed applications are relatively easy to implement and all of them would create at least some benefit to society and to the Highways...
Agency. But the difficulty lies in the deployment of the system. How do we make sure that more and more people are willing to pay for these systems to be installed in their vehicles? A carefully selected application or a bundle of applications might generate enough demand, but this alone does not answer the question of who should pay for the infrastructure part of the system. This investment most likely has to be taken up by the road operators, and for them it is important to know which application(s) are most likely to be used initially and which have the potential to provide the greatest return on their investment.

Using the method summarised in Section 4.1 the applications described above were scored and ranked in order of priority for the Highways Agency. The scoring system resulted in four applications rated as 'high' priority, 21 'medium' and 15 'low' priority. The scores assigned to each of the applications on each of the dimensions considered are shown in Table B.1 (overleaf).

In considering the results of this process of prioritising application, the following points should be borne in mind.

Given the current state of co-operative systems, with substantial uncertainties at all areas, the analysis is subjective, providing indications of priority that can be used to guide the direction of further investigation, rather than a quantitative assessment. Many of the applications and scores can be interpreted in different ways, producing different results. One key element of uncertainty is the technology solution chosen to implement the application (e.g. Infrastructure based or V2V based application), which can have a major effect on the penetration level required for that particular application to be effective.

Another example of uncertainty is that one possible scenario for the future can be envisaged in which some motorways will be available only to vehicles with fully equipped co-operative systems. In this case some applications, for example ‘In vehicle signage’ would generate a high business case for Highways Agency, due to the fact that no physical signs (e.g. Variable Message Signs - VMS) would be needed at the side of the road; but currently this application is rated as having a low business case because of the continued need to provide signs to offer a service to all including non-equipped vehicles. An alternative and more likely scenario would be to provide ‘basic’ VMS signs (at much lower cost) for non-equipped vehicles.

Changes in social and political priorities could also bring about changes in the ranking of some of the applications. For example the ‘Vehicle noise & emissions warning’ application is currently rated as a low priority for the Highways Agency, but it could be easily taken up by political groups and its priority could change dramatically, even though the technology and the business case remain the same.
Table B.1 Cooperative Systems Applications and Services Prioritisation

<table>
<thead>
<tr>
<th>Application or Service (description)</th>
<th>Potential Societal Benefits(^1)</th>
<th>Definition of overall business model(^2)</th>
<th>Potential strength of HA business case(^3)</th>
<th>Degree of penetration required(^4)</th>
<th>HA role in delivery chain(^5)</th>
<th>Resultant HA priority(^6)</th>
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<tr>
<td>Dynamic network performance information to travellers (1)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>13 HIGH</td>
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<td>Intelligent speed adaptation [ISA] (2)</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>12 HIGH</td>
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<td>Eco-driving support (3)</td>
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<td>2</td>
<td>2</td>
<td>3</td>
<td>12 HIGH</td>
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<tr>
<td>In-vehicle signs and visibility enhancer (4)</td>
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<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>12 HIGH</td>
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<td>Traffic jam ahead warning (5)</td>
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<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>11 MEDIUM</td>
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<td>Intelligent on ramp metering (6)</td>
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<td>HA role in delivery chain</td>
<td>Resultant HA priority</td>
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<td>Definition of overall business model</td>
<td>Potential strength of HA business case</td>
<td>Degree of penetration required</td>
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<td>Resultant HA priority</td>
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Notes:
1. Overall benefits to society in terms of reduced numbers of accident casualties, reduced delays due to congestion and reduced emissions. (High=3, Medium=2, Low=1).
2. Degree to which costs and benefits are known which is a proxy for the maturity of the application/service. (Good=3, Moderate=2, Poor=1).
3. The degree to which a business case for HA involvement in delivery of application/service can potentially be made. (High=3, Medium=2, Low=1).
4. The degree to which costs and benefits are known which is a proxy for the likelihood of appreciable benefits which is a proxy for the likely timeframe for delivering the benefits. (High=3, Medium=2, Low=1).
5. The degree to which the HA would be involved in the delivery of the service. (High=3, Medium=2, Low=1).
6. The resultant summation of the scores for each criterion (High=15, Medium=14, Low=13).
Cooperative vehicle highway systems – implications for the Highways Agency

The capability to exchange information between vehicles and between vehicles and roadside infrastructure in co-operative vehicle systems creates many opportunities for innovation in the way in which the road network is used and managed. This will not only involve the introduction of new technologies, but also in the way in which road operators, vehicle manufacturers, service suppliers and other stakeholders work together to provide services for travellers using the road network, with mutual benefits for all.

This report was written in 2010 and draws on current projects and recent experiences at that time. An overview of the status of developments in co-operative vehicle systems at that time is provided to assist the Highways Agency in assessing the implications of future deployment of such systems on the road network. The findings are informed by the experience gained while participating in the European CVIS (Co-operative Vehicle Infrastructure Systems) project.

The ‘state of the art’ of co-operative vehicle systems is reviewed, recent projects and developments in Europe, the USA and Japan are summarised and applications are analysed and priorities identified for the Highways Agency. Implementation issues are discussed, and issues for the Highways Agency are summarised. Recommendations are made for further Highways Agency activities to take forward the development of co-operative vehicle systems.

Other titles from this subject area

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PPR294  Research on the manufacturing of DSRC Tags: summary of results for publication. D W Tindall. 2008
PPR259  Occlusion Protocol. T Horberry, A Stevens, S Cotter, R Robbins and G Burnett. 2007
PPR256  Development of an Occlusion Protocol with design limits for assessing driver visual demand. T Horberry, A Stevens, S Cotter, R Robbins and G Burnett. 2007