External Vehicle Speed Control

Phase I Results

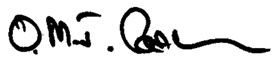
Executive Summary

June 1998

Project Partners:
The University of Leeds and The Motor Industry Research Association

Project Funded by the Vehicle Standards and Engineering Division
Department of the Environment, Transport and the Regions

INSTITUTE FOR TRANSPORT STUDIES
DOCUMENT CONTROL INFORMATION

Title	External Vehicle Speed Control, Phase I Results: Executive Summary
Author(s)	Oliver Carsten and Mark Fowkes
Editor	Mark Fowkes
Reference Number	EVSC–Exec1
Version Number	2.1
Date	3 June 1998
Distribution	Public
Availability	Unrestricted
File	C:\External Vehicle Speed Control\Executive Summary of Phase I.doc
Authorised	O.M.J. Carsten
Signature	

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1. INTRODUCTION

The External Vehicle Speed Control project has the aim of reviewing a broad range of factors related to the possible introduction of an automatic system to limit the top speed of road vehicles The system was previously raised as a potential future tool for traffic management by the UK Department of Transport in their 1996 consultation document, “A Policy for using new telematic technologies for road transport”.

This document states:

51.The Government aims (a) to promote the use of transport telematics to reduce road accident casualties where practicable and cost effective; and (b) to ensure that the use of telematics does not adversely affect safety. Monitoring and enforcement applications of telematics offer significant potential to improve road safety.

52.The Government has a range of research projects to assess the potential of new technologies for improving road safety. For example, the enforcement of safe and appropriate speeds through telematics-based speed management and control is a promising area for casualty reduction. More effective enforcement of safety-related traffic offences could also be facilitated through use of image recognition technology. Other important safety related applications include driver assistance to avoid collisions with other vehicles and vulnerable road users. And the use of cameras for speed limit and red light enforcement..

This consultation document then describes the *potential* implementation of the functionality of such a system as:

53.Research shows that vehicles travelling at excessive speeds are more likely to be involved in injury accidents. It is a factor in one third of all road accidents. Currently some 1,200 fatalities on roads in Great Britain each year are therefore partly attributable to excessive or inappropriate speed. An automatic speed control system would use some form of roadside transmitter to send speed limit information to passing vehicles. These vehicles would have an on-board system linked to the throttle/brakes to prevent them from exceeding the received speed limit. Automatically controlling vehicle speed from the roadside could significantly reduce the number and severity of accidents, particularly among vulnerable road users. It could also reduce emissions and improve traffic flow. However, a number of issues relating to the costs, benefits and disbenefits of automatic speed control remain, so the Government is commissioning a research programme to investigate them.

It was assumed at the outset that such an EVSC system would have to be:

- Cost-effective
- Acceptable
- Logistically feasible
- Safe

This Executive Summary summarises the results of the Phase I of the project. This phase of work began in February 1997 and ended in October 1997 and was designed as an introductory stage to prepare for the detailed design and experimental work in Phase II. It covered work in the following areas:

1. The relationship between speed and accidents
2. Review of previous work on speed control
3. Links with other projects, both within and outside the UK

4. The technical design of the system including communications, system logic and the control mechanisms
5. Acceptability
6. Implementation scenarios and predicted safety benefits
7. Legal implications

This document presents summaries of the deliverables produced by the research team on these issues.

2. DELIVERABLE 1: REVIEW OF THE LITERATURE ON THE RELATIONSHIP BETWEEN SPEED AND ACCIDENTS

This report reviewed around 120 previous studies, looking for example at the physics of speed and its effect on accident frequency and severity, the effect of speed on accidents to vulnerable road users, the impact of weather, surface condition and light condition on speed-related accidents, and the impact on accidents of various speed reduction methods.

The conclusions of the review were that the strength of the relationship between speed and accidents was incontrovertible. It is not just a case of a small number of accidents being caused by excess or inappropriate speed, but rather of accident risk being generally related to speed. Increases in speed of travel lead to increases in the risk of an accident occurring, and of accident severity should one occur. However, in spite of the large amounts of research that have been carried out, there is still disagreement about the exact nature of the relationship between mean speed and accidents, and some reason on theoretical grounds to question some of the conclusions that have been drawn. Thus the finding of Finch et al. (1994) of a *linear* relationship between mean speed and injury accidents is not credible for all ranges of speed. Some kind of asymptotic function (e.g. logistic), as proposed by Salusjärvi (1988) and Nilsson (1990), is far more plausible. Such a function would suggest that changes in mean speed for very low or very high levels of mean speed have proportionately less effect on injury accidents and casualties than do changes in the mid-range of speeds.

In addition to mean speed, there is some evidence to suggest that speed variance has an effect on the accident rate, although here the evidence is somewhat contradictory. When speed variance is reduced by having the slower drivers drive faster, the result is an increase in mean speed and in accidents. Only when reductions in speed variance are accompanied by reductions in mean speed do accidents decrease (Salusjärvi, 1988). The implication is that reducing speed variance by curtailing the speed of the fastest drivers is an effective safety measure, but that reducing variance by increasing the speed of the slowest drivers is not. This points to the likely benefit of measures to control the maximum speed of vehicles, provided that this is not done in a non-uniform manner by limiting the maximum speed of particular classes of vehicle and hence perhaps increasing speed variance, especially on fast roads.

In terms of particular types of accident, two groups of accidents were identified as deserving special attention. They were:

- accidents on urban roads involving vulnerable road users
- accidents on rural two-lane roads at below-standard horizontal curves

In terms of accidents involving vulnerable road users, the conclusions of Pasanen and Salmivaara (1993) suggest that very substantial impacts on pedestrian casualties can be obtained with reductions in driving speeds on urban roads. Reducing mean speeds from 40 km/h (25 mph) to 30 km/h (19 mph) would result in a reduction in fatalities to pedestrians of about 50 percent. However, below a mean speed of 20 km/h (12 mph), there is little further benefit in terms of pedestrian fatalities to be obtained.

As regards substandard horizontal curves on two-lane rural roads, there is ample evidence that drivers do not adapt their speeds very well to them and that as a consequence they are a considerable safety problem. Wet road conditions and darkness both exacerbate the problem — in neither case do drivers adapt their speed to the substantial increase in risk.

However, while the relationship between curvature and speed has been studied, there has been less work on the relationship between curvature and safety, so that it is not as easy as it is in the case, for example, of urban roads, to hypothesise that a given change in mean speed will have a given impact on the accident rate. There has also been less study of the effect of particular measures to control speed on the actual speed of traffic.

Another conclusion was that automatic control of vehicle top speed would have a different effect on speed distributions than most other measures designed to affect speed. Many other measures, with the possible exception of police enforcement, will change the behaviour of drivers across the speed spectrum. In theory at least, speed control could alter the speed distribution so that the speeds of drivers below the cut-off point are not affected at all and only the fastest drivers have their speeds changed. If this were the case, then in many situations mean speeds might be affected comparatively little but the 85th percentile speed could be virtually identical to the 100th percentile speed. Such a distribution is not one that has been encountered previously to any great extent — even with stringent enforcement some drivers will continue to violate. It was indicated that this would have important implications for modelling work which could try to extrapolate the effect of automatic speed control on accidents.

3. DELIVERABLE 2: REVIEW OF RESEARCH ON EXTERNAL VEHICLE SPEED CONTROL

This report reviewed both the relatively small number of behavioural studies carried out with speed-limited vehicles and a number of studies using simulation modelling and other tools to predict the impact of EVSC. It also covered the relevant research on communications and control systems.

The conclusions were that the published literature reinforces the impression that conventional speed limiting measures do not prevent a large proportion of drivers from exceeding the legally imposed maximum road speeds. Consequently, additional measures are required to improve compliance with the aim of reducing the frequency and severity of road accidents. However, both simulator and field studies have demonstrated driver compensatory behaviour in reaction to speed limiting. Such behaviour, in the form of unsafe driving in the vicinity of junctions and other road users could diminish any safety benefits found elsewhere. It is therefore imperative to evaluate the likely impact of EVSC in terms of safety benefits and costs in a variety of safety critical situations. Driver comfort and mental workload are also issues of importance, and new concepts such as engine braking and active gas pedals should be evaluated in terms of acceptability to the driver. Simulation models have tended to imply reductions in speed variance when implementing EVSC, although as stated in Deliverable 1, a close inspection of the speed distributions should be made to discover how this might relate to accident rates.

A taxonomy for consideration of EVSC hardware was proposed, i.e. the source of the *limiting signal*, *communication device* and *control mechanism* employed to enact control. It can be seen that the required technologies for enactment of speed control, in the most part, already exist. Thus, the chief task in the development of EVSC is the selection and integration of available component parts and sub-systems. For example, an on-board vehicle speed limiting mechanism may be interfaced to data supplied by roadside infrastructure to provide a method of enacting dynamic local road speed limits to:

- reduce excess speed
- control speeds around an accident site or environmental hazards
- manipulate traffic flows.

Clearly the choice of candidate technologies to perform an EVSC function is dependent upon their cost-effectiveness and availability in the market. There is therefore a need to address what technologies will be available over a range of timescales to an eventual implementation as EVSC as a viable traffic control measure. This review identified several key potential technologies that are currently emerging and that could have an applicability for EVSC functionality. These include Adaptive Cruise Control (ACC) which could provide a traffic sensitive on-board mechanism for carrying out speed limiting. This could be interfaced to a Dedicated Short Range Communications (DSRC) network to enable locally targeted updates of the prevailing or recommended speed limit. But in this context, it is important to bear in mind the somewhat negative results of the trial with a modified ACC in Sweden (Almqvist and Towliat, 1993).

4. DELIVERABLE 3: LINKS WITH OTHER TELEMATICS PROJECTS

This report reviewed the current position of known telematics technology projects directly related to EVSC. It first examined the factors that have influenced the development of transport telematics and then examines the current status of projects that have a relevance to EVSC. It concentrates primarily on those projects that are in progress across Europe, at both EU and national levels. A review of research activity in other continental areas, notably North America and Pacific Rim, was also carried out but little activity of direct relevance to EVSC has been found. The report considers both the overall direction and objectives of these projects, but does not at this stage consider in depth their detailed technical progress as this information is not currently available. For each of the projects assessed a brief overview of the objectives of the project is given, together with a description of the proposed workplan and timescale. Details of the organisations involved and the main contact points are also given At a European level projects within the R & TD programmes of Directorate-Generale VII (Transport) and DGXIII (telematics) were surveyed. Particularly relevant projects to the implementation and evaluation of Telematics systems like EVSC and potential technology developers of relevance have been highlighted. Projects of particular relevance are described below.

4.1 EU TRANSPORT RESEARCH PROGRAMME — DGVII

- DIATS **(**Deployment of Interurban ATT Test Scenarios) which seeks to; identify likely options for implementing "co-operative driving", develop scenarios of "highest potential impact" for each of the systems identified, identify the elements needed to successfully deploy these ATT measures in field tests, and create awareness of the potential.
- DUMAS (Developing Urban Management And Safety) which will; collate research findings and current practice relevant to urban safety management, investigate areas where knowledge is lacking, design of a framework that will identify all the elements that need to come together in an area-wide urban safety management project, analyse and assess the available accident data to identify a methodology for accident analysis and a framework for design and assessment, examine evaluation methods for speed management in urban areas, consider a general concept for setting up a speed management programme. A general concept for assessment/evaluation of speed management principles implemented.
- MASTER (MAnaging Speeds of Traffic on European Roads). The aim of the project MASTER is to provide recommendations for speed management strategies and policies and develop guidelines for the development of innovative speed management tools, The approach is comprehensive, in addition to safety it takes into account also other factors which are relevant in the definition of adequate speed management policies.

4.2 EU TELEMATICS APPLICATION PROGRAMME — DGXIII

- AC-ASSIST (Anti-Collision Autonomous Support and Safety Intervention System) The AC ASSIST project will address the needs of drivers for systems to support the driving ask, specifically in critical situations. Its focus is on the validation of autonomous systems capable of providing anti-collision assistance and vehicle control. The aim is to demonstrate warning and intervention functions that provide Collision Avoidance along the longitudinal axis of the vehicle.
- UDC (Urban Drive Control) The intention behind the Urban Drive Control project is to integrate environment and city management with individual drivers' interests, by combining remote driving speed recommendations with autonomous longitudinal control of vehicles. The project will adapt and improve the existing technology, which has been developed for speed and distance control on highways, for operation in urban areas. The objective is to integrate traffic management and vehicle longitudinal control.
- RESPONSE This project will start in 1998 and intends to examine the legal and liability issues related to the deployment and market uptake in telematics systems. This investigation will include a detailed review of the process by which technical concepts have been selected, evaluated, developed and approved.

4.3 NATIONAL PROGRAMMES

UK Foresight — The Road Traffic Advisor project is a multi-partner collaborative project under the Foresight initiative. Road Traffic Advisor seeks to demonstrate an open architecture driver information and traffic management telematics system. The system is based upon dedicated short-range communication (DSRC) technology operating in the 5.8GHz frequency. Roadside beacons operating with DSRC will exchange information with a test fleet of appropriately equipped vehicles. The workplan will examine a range of technical issues in relation to the provision of such a service. This will include an assessment of the implications of such a communications link to the delivery of speed limit related information. In particular this will be examined in the context of the variable speed limit management of a section of the M25 motorway.

Sweden — The Swedish National Road Administration has instigated a series of practical evaluations of EVSC functionality that it terms "Intelligent Speed Adaptation" (ISA). They have so far performed two initial field tests of such technology. The first was in the Swedish town of Umea and involved 100 vehicles equipped with a driver advice device. This device received a message from a roadside beacon that was associated with speed limit boundaries and transmitted the appropriate speed limit on a frequency of 433 MHz. Within the test vehicles this "set" speed value is compared with the vehicles actual speed and if the driver exceeds the limit a simple auditory and visual signal is given to the driver.

Following this a second trial was conducted in the Swedish city of Eslov where 30 vehicles were retro-fitted with an intervention system that forced the vehicle to slow if it exceeded the actual limit (50km/h). When equipped cars pass the transponders on entry roads into the city the vehicle speed limiter system is automatically set on the 50 km/h limit. When the cars leave the urban area the speed limiter is disengaged. Trials have also been made of an on-board electronic map database (CD-ROM) with speed limit information together with a GPS sensor to give location information. Such a technology could ultimately reduce the need for a dedicated infrastructure and hence have wider applicability. These were relatively small-scale trials and have not yet enabled a verification of the safety benefits of such a system. However preliminary results have supported a plan for a two larger trials in two different geographical locations. This may involve thousands of vehicles and could commence in 1998/99.

Netherlands — In July 1996, the Minister of Transport, Public Works and Water Management of the Netherlands presented a new multilayer programme for road safety including a feasibility study to assess the possible application of using intelligent speed adaptors (ISA), an alternative term to EVSC. The project assessed how a trial could be established in a new suburban housing estate in Tilburg. In this feasibility stage it was considered that a series of restrictive architectures to restrict vehicle speeds in housing areas would be supplemented by technology applied to the new residents own vehicles to restrict vehicle speeds within those areas. The main aim of the proposed project would be to increase public acceptance and support to such a device. The study hopes to deal with aspects such as technical feasibility, integration, legal framework and organisational consequences.

The report details the discussions held on EVSC/ISA at Brussels in October (Telematics Programme Meeting) and Berlin (4th World ITS Congress) in November 1997. The recent discussions held at these two workshops indicate the currently opposed views between the government bodies and research groups (who broadly favour further investigation of EVSC) and vehicle manufacturers (who have declared a sceptical view on the acceptability and liability issues). It seems that this discrepancy is in part brought about by the lack of a clear understanding about the range and type of functionality that may be implied by a "EVSC". Further presentation about how such a system could be employed and implemented is therefore required. Further contact between members of the national project teams in all three European countries has indicated a potentially beneficial complimentarity between the planned activities and a further meeting is planned for early 1998.

5. DELIVERABLE 4: TECHNICAL APPROACHES TO THE IMPLEMENTATION OF EXTERNAL VEHICLE SPEED CONTROL

This report assessed the vehicle technology issues associated with the development and application of an EVSC system. It assessed the many possible factors of vehicle construction, powertrain options and types of vehicle to attempt to examine how EVSC functionality could be developed. It also examines the potential timescale implications for the introduction EVSC. A phased introduction of technological interventions has been proposed and the consequences of such a multi-level EVSC has been considered in detail and a full preliminary safety assessment has been carried out.

It was assumed from the outset that such a system would have to be; safe, cost-effective, acceptable and logistically feasible. It would also have to be potentially applied to a wide range of types of vehicles, engines and transmissions and function in a wide range of road, traffic and environmental conditions. In order to consider the possible technical approaches to providing an EVSC functionality, a parallel application of both "top-down" and "bottom-up" approaches was employed. A "top-down" establishment of a functional definition, conceptual framework and system evaluation methodology was derived. In parallel a brainstorming team was utilised to develop a range of engineering approaches for EVSC functionality as a complimentary "bottom-up" approach. The initial functional definition of an EVSC system was derived as:

An ***external vehicle speed control*** system is one that effectively influences the speed of road vehicles. It should not inhibit current or potential enforcement mechanisms. It should define the process required to transmit speed restriction data to the vehicle or driver and be aware of the vehicle's location with respect to the local speed limit. System performance should comply with that expected from a 'state of the art' automotive product and its enactment should meet with the reasonable expectations of the vehicle user. It should affect all types of road and road vehicle.

This global definition for an external vehicle speed control mechanism was then used to provide a simple conceptual framework for an EVSC. This conceptual framework having three principal *sub-components*. These were described as:

- **Traffic Control** (i.e. the instigator of speed limits and the operator of legal enforcement mechanisms, e.g. government departments, infrastructure managers, enforcement agencies)
- **Communications** (i.e. the means by which the speed limit information is disseminated to, and within, the vehicle/driver, e.g. short range communications, vehicle databuses, visual displays)
- **Driver and Vehicle Control Systems** (i.e. the mechanisms on the vehicle that react to the speed limit information, e.g. the driver, accelerator, brakes, traction control etc.)

This framework therefore also contains an implicit additional component to **enforce** a legal requirement for vehicle speed. This framework is illustrated in the figure below.

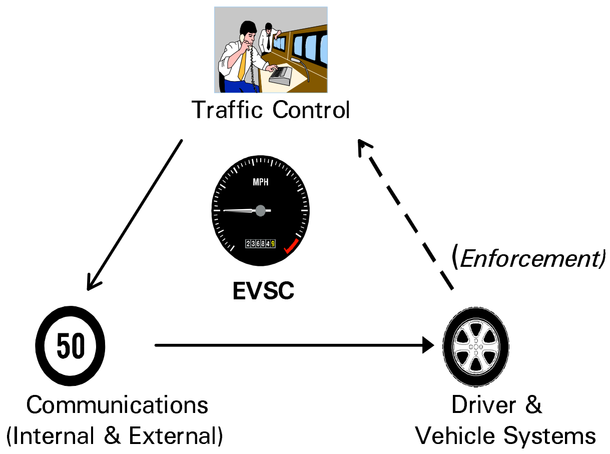


Figure 1: Schematic of functional sub-components of EVSC

A wide range of both potential technical approaches and operational issues relating to EVSC were produced by the brainstorming exercise and an evaluation matrix applied. This evaluation considered a number of factors such as, the desired *timescale* to implementation, the specific *focus* of the application, the *maturity* of the required technology, and the establishment of appropriate cost and system *effectiveness targets*. As a result of this analysis it was concluded that a range of potential complexities and levels of control of EVSC could be conceived. These included:

- *Advisory measures* which could emerge in the forum of the communication of local speed limit information as an additional source of driver information. The objective of this process is to more directly effect changes in driver behaviour with relation to speed control, i.e., an indirect control mechanism. Using current broadcast media under development it is possible that a range of delivery mechanisms for this can be considered integrated with other telematics applications. Such systems could be in place in five years time. For example, an In-vehicle speed limit indicator
- *Advisory intervention* measures could form a second stage of EVSC development. Speed limit data could be employed by the vehicle system to effect “stronger” advice to the driver. This could be implemented through vehicle control related speed exceedance (and severity) warnings, e.g., via a haptic throttle that provides resistance to the driver if he tries to apply more power to exceed the speed limit, but that could still be overridden by the driver. Although technically feasible for a five year introduction horizon acceptability issues with respect to such systems would have to be clarified.

- *Mandatory Intervention Measures* could be the third stage of implementation of EVSC. Speed information would be used to physically limit vehicle performance to the prevailing speed limit. It may therefore have to be considered that such a system would have to be applied as one that is on a mandated basis via both vehicle construction and road law obligations. Here the *broadcast* speed limit information would be used by the vehicle control systems to physically limit the maximum speed achievable by the vehicle. Obviously such a system must be capable of being proven and abuse of the system prohibited. With the lengthy timescales to introduce such a system with possible public acceptability questions a horizon of fifteen years is suggested here.

Other national initiatives, in Sweden and the Netherlands, are also currently investigating various possible implementations of EVSC and have been described earlier. It may be summarised here that there is not a common technical approach to the implementation of EVSC, or Intelligent Speed Adaptation (ISA) as it is sometimes alternatively termed. However it is commonly accepted that the three "levels" of EVSC functionality described above are those that have to be explored. The implications for evaluation of the technical concept of an EVSC is that an analysis of all possible levels of EVSC is required particularly with regard to an assessment of the consequences of the "failure" of such a system in service.

There are three possible EVSC scenarios to consider that are relevant to the levels described above:

a) An "Advice" only system, i.e. SL information displayed to the driver within the vehicle
b) A "User-set" system, i.e. SL information displayed to the driver within the vehicle who selects compliance with the SL maximum speed
c) A "Full system" that receives SL information and automatically sets a maximum vehicle speed

In order to examine how this may be realised a Preliminary Safety Analysis (PSA) was carried out on an EVSC system. Firstly some assumptions were made concerning the engineering components likely to be employed to fulfil the roles of the sub-components of EVSC. Following this a diagramatic representation of a generic EVSC was produced based upon the methods of the DRIVE project PASSPORT.
Figure 2 shows a PASSPORT Diagram for a "Full" EVSC system. It identifies the components and organisations responsible for specifying designing and developing an EVSC. The different "levels" of EVSC functionality would be achieved by different sub-sets of these components and organisations.

On the left and right hand sides of the PASSPORT Diagram are the inputs and outputs to and from the system respectively; note that all these terminators are WITHIN the system boundary. At the top of the diagram are various 'static' inputs upon which the system depends, or that will have an influence over it. At the bottom some groups of data, which will be important for the correct functioning of the system, have been identified explicitly; these are normally stored within the Nucleus.

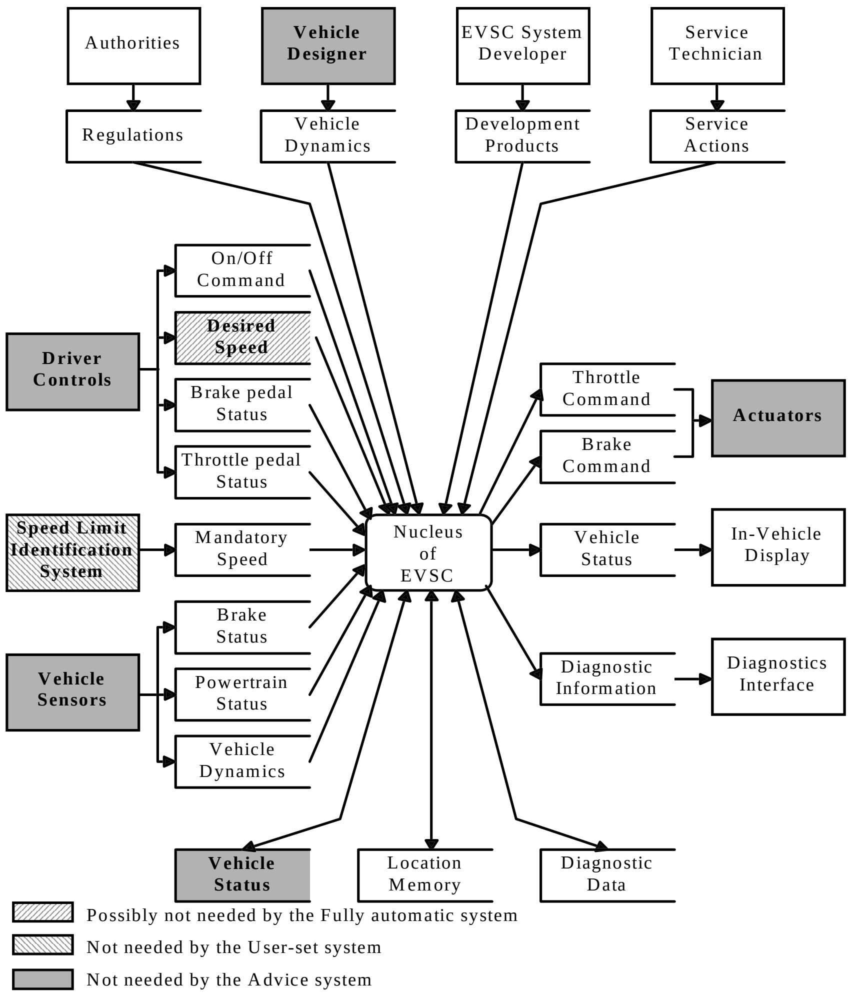


Figure 2 — PASSPORT Diagram of a Full EVSC system

An analysis of the hazards identified during the PSA for all three levels of EVSC was performed and a definition of their "controllability" was given. In this context the controllability categories used are defined as follows (MISRA 1994):

Definition of Controllability Categories

Controllability Categories	Definition
Uncontrollable	This relates to failures whose effects are not controllable by the vehicle occupants, and which are most likely to lead to extremely severe outcomes. The outcome cannot be influenced by a human response.
Difficult to Control	This relates to failures whose effects are not normally controllable by the vehicle occupants but could, under favourable circumstances, be influenced by a mature human response. They are likely to lead to very severe outcomes.
Debilitating	This relates to failures whose effects are usually controllable by a sensible human response and, whilst there is a reduction in the safety margin, can usually be expected to lead to outcomes which are at worst severe.
Distracting	This relates to failures which produce operational limitations, but a normal human response will limit the outcome to no worse than minor.
Nuisance Only	This relates to failures where safety is not normally considered to be affected, and where customer satisfaction is the main consideration.

A study of the hazards identified during this analysis shows that the possible failure scenarios are of two basic types. Four failure scenarios, with controllabilities Distracting and Debilitating, are the result of a failure of some part of the EVSC system only, however a further three failure scenarios will only occur if the driver is not driving with due care and attention to the conditions of the road, and are therefore not hazards due to a failure of the EVSC system alone. For this reason these three hazards were not considered further.

It was concluded that the following safety objectives should form the basis for the validation plan for any EVSC system.

- The EVSC system must never perform an action that will place the occupants of the vehicle in any danger.
- The EVSC system must never perform an action that will place other road users in any danger, or causes them to take evasive action.

In addition some features which were identified as being necessary for EVSC during the PSA.

1. The driver should be informed as to when the EVSC system is active.
2. When the EVSC system is active the driver should be informed of the speed limit currently being used by the EVSC system.
3. The driver should be able to set a “Desired Speed” that is different from any “Mandatory Speed” that may have been received. This would be the case if there were both ‘auto’ and ‘manual’ settings under the control of the driver.
4. In the last resort, the driver should be able to disable the EVSC system.
5. The driver should be informed when the Location Memory has ‘lost’ its data

There were also features that have been identified to deal with specific hazards and should be born in mind for any implementation of EVSC.

6. The driver must always be able to have ‘manual’ control over the brakes.
7. The beacons should be sighted so that their line-of-sight with the passing traffic is unlikely to be blocked.
8. The beacons should be sighted such that the EVSC system should not cause automatic braking on a corner.

A subsequent “what causes” analysis was performed to assess where additional measures should be taken to establish where particular instances of potential faults may be countered by particular emphasis being placed in the engineering development of an actual EVSC mechanism.

This report therefore assessed how a technical implementation of EVSC could be produced. It examined a large number of possible mechanisms for EVSC that could be utilised. It also reviewed the applicability of these mechanisms to the wide range of types of road vehicles. It summarised that control mechanisms that would introduce active retardation of vehicle road speed would produce the greatest level of engineering complexity. It therefore infers that if such a implementation were required then this would have to be as an integrated input into the vehicle dynamics control system to ensure vehicle stability. Therefore at the current level of analysis the application of an active retardation system for two-wheeled powered road vehicles could prove particularly difficult. A further examination of these issues is planned in subsequent phases of the project.

6. DELIVERABLE 5:
ACCEPTABILITY OF EXTERNAL VEHICLE SPEED CONTROL

Two complementary studies were carried out on attitudes towards EVSC. The first was a household survey using Stated Preference techniques. The second study used structured focus groups of invited participants drawn from a range of relevant backgrounds.

6.1 HOUSEHOLD SURVEY

Stated Preference (SP) surveys present decision makers with hypothetical alternatives characterised by variables which are of interest to the analyst and which influence preferences between the alternatives. The preferences stated amongst the alternatives provide information on the relative importance of the variables given that there are trade-offs amongst the levels of the attributes characterising the alternatives. Preferences can be expressed by stating a choice between a number of alternatives, of which pairwise comparison of two alternatives is by far the most common choice exercise, or by ranking a series of alternatives. It is the purpose of the modelling stage to estimate how changes in the attributes which characterise the alternatives impact on the choice or ranking, that is, to establish the relative importance of these attributes.

The survey examined drivers' and residents' attitudes towards and preferences amongst three different measures which could be adopted in order to reduce traffic speeds. The three measures investigated were speed cameras, vehicle speed limiters, and traffic calming. The survey was conducted in a residential area of Bradford, West Yorkshire, in a reasonably affluent part of the City and one in close proximity to an area with existing traffic calming measures, so that respondents would be familiar with such schemes. Successful interviews were conducted with 159 individuals, 88 of whom completed the drivers' questionnaire and 71 of whom completed the residents' questionnaire. The respondents were split on gender as follows:

	Drivers	Residents
Male	46	32
Female	42	39

Prior to the SP questions, the respondents were asked a number of questions speeding and about how acceptable and how effective were various methods of controlling speeding — more speed cameras, on the spot speeding fines, more traffic calming, stricter speed limit enforcement, speed limiters, and disqualification for various periods

The results of the survey indicate that speeding was generally recognised as a major cause of accidents. In terms of remedial measure, more enforcement was the most acceptable method of speed reduction, but speed limiters were also acceptable, especially to residents. In terms of effectiveness of alternative remedies, speed limiters were rated as most effective. The SP results indicate that the drivers were willing to spend £97 p.a. for traffic calming; £100 p.a. for local speed limiters; £145 p.a. for speed cameras everywhere and £148 p.a. for speed limiters everywhere. The residents were willing to pay £18 p.a. for traffic calming (in their area), £22 p.a. for speed cameras and £15 p.a. for speed limiters.

6.2 FOCUS GROUPS

The focus group discussion is a common tool for assessing the publics' attitudes about products or services. A focus group consists of a small number of people who are brought together to evaluate and identify concepts and issues. A neutral moderator acts as the chairman and is responsible for the overall running of the session and guiding the participants through the issues in a relaxed and free flowing manner. The sessions are recorded to facilitate qualitative analysis. The focus group composition was as follows:

Focus Group 1	***Focus Group 2***	***Focus Group 3***
Traffic Management Police	Council Pedestrian Officer	Member of the Institute for Advanced Motorists
ROSPA district leader	Representative from Pedestrian Association	Representative from Friends of the Earth
Member of the Institute for Advanced Motorists	Representative from Transport 2000	Traffic Management Police
Member of the Institute for Advanced Motorists	Police Driving Instructor	General Public
Member of the Institute for Advanced Motorists	Representative from the Bicycle Users Group	General Public
Local Fleet Manager	Representative from Motorcycle Action Group	General Public
Motorcyclist	Traffic Management Police	General Public
National Motorsport Competitor	General Public	General Public
Novice driver	General Public	General Public

A list of key issues was sent to the participants in advance. At the beginning of each session, there was a short presentation by the moderator on the concept of EVSC. Then a general discussion was encouraged on the benefits, costs and acceptability of EVSC. Each session was tape recorded and the tapes were subsequently analysed for common themes and issues.

The results indicated a general resistance to the concept of speed control, mostly because it was felt that although exceeding the speed limit is a contributory factor in a proportion of accidents, inappropriate speed in constantly changing road and traffic conditions was a more important issue. It was generally thought that a speed control system would not be adaptable enough to take account of small changes in the traffic system. It was suggested that a system such as speed control that takes control away from the driver could lead to the loss in skills in 'reading the road'. There were calls for more intense further training such as that offered by ROSPA or IAM to be compulsory to cover aspects such as driving in adverse weather conditions and motorway driving. Re-testing was recognised as being costly but was seen as a way of creating funds and decreasing the volumes of traffic. Poor driver attitude was seen as a contributory factor to many accidents, whereby drivers are under the impression that they have a right to speed. Publicity campaigns and increased road safety education in the school curriculum were seen as ways of addressing poor attitudes.

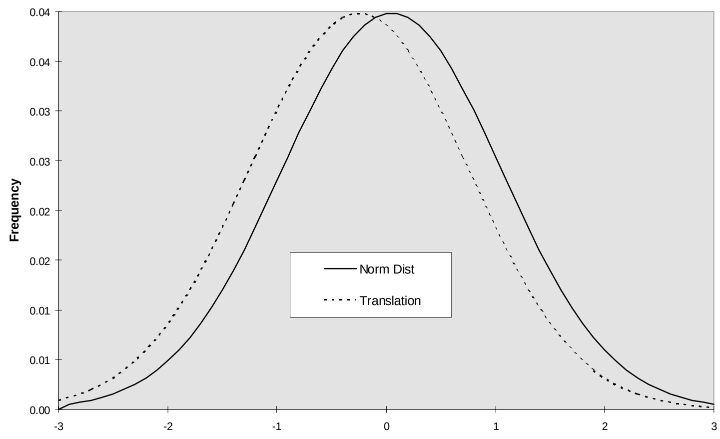
In terms of enforcement, it was thought that currently enforcement is poorly funded, and that ideally there should be a higher police presence and more stringent enforcement and penalties. Speed cameras were seen as being effective to start with but in time it was thought the effect would diminish. Speed control of some sort was welcomed, but the idea of control being external to the driver was not well received, and it was commented that public acceptability was likely to be low at first. However, it was thought if implemented it should be a mandatory system, whose launch should be combined with a positive marketing and lowered costs in terms of for example insurance premiums.

7. DELIVERABLE 6: IMPLEMENTATION SCENARIOS

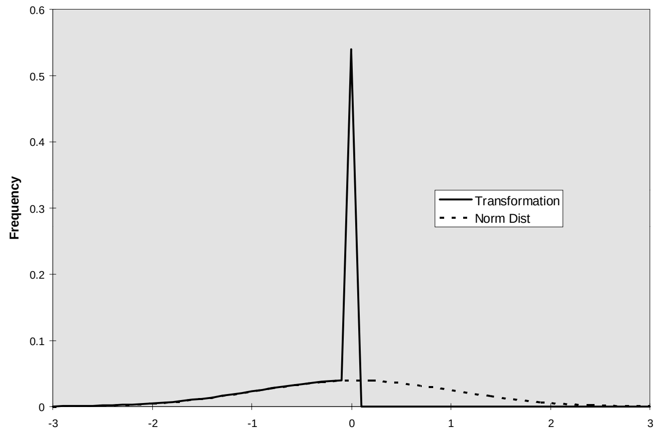
This report considered the effectiveness, measured in accident reduction benefits, of various forms of external vehicle speed control (EVSC) and the costs of implementation. The report considers first the ways in which EVSC may affect traffic speeds and thereby generate accident reductions and economic benefits. The components of possible systems, and sub-systems, are then considered and the costs of the systems established. An economic analysis follows in which the benefits and costs are combined and feasible implementation scenarios are identified on the basis of the resulting benefit cost ratios (B/C).

7.1 BENEFITS

A review of other studies that seek to quantify the role of speed, and therefore the likely accident reductions related to speed control, has identified two typical approaches. Some studies consider only those accidents in which inappropriate speed is identified as a causal factor while others look at the effect of speed changes on all accident types combined. Neither approach is considered adequate on its own. As speeds are reduced potential benefits arise for all accidents as driver reaction time and evasive action are improved. This will not only reduce the likelihood of an accident occurring but also reduce accident severity so that some injury accidents may become damage only accidents. When considering only those accidents where speed is identified as a causal factor, these benefits are lost. On the other hand considering only the relationship between speed and accidents in general, neglects the fact that EVSC will have a greater impact on speed-related accidents. Research has indicated that the propensity for speed of individual drivers is related to their personal accident liabilities. On this basis the investigation has considered the way in which different types of EVSC will effect the shape of the distribution of vehicle speeds. Two mechanisms have been defined: *Translation* in which the shape of the speed distribution remains essentially the same but the overall distribution is translated downwards with respect to speed; and *Transformation* in which the speed distribution is truncated, with no vehicles exceeding the speed limit. These two mechanisms respectively represent the effects of an advisory and a mandatory system of EVSC. They are illustrated below with two hypothetical distributions.



Translation



Transformation

The level of accident reduction was then calculated on the basis of the type of speed advice supplied to the driver. In this respect three types of speed limit system have been identified:

1. A system with fixed speed limit categories, i.e. the limit is set to the legal maximum for each stretch of road ;
2. A variable system in which local speed limits may be set to account for poor road geometry and the like;
3. A system incorporating dynamic speed limits which may account for changing road surface, weather and visibility conditions.

Combining the two system states, advisory and mandatory, with the three versions of speed limit, fixed variable and dynamic, provides six EVSC scenarios. Using results from a variety of sources, estimates have been made of the reduction in accidents that could be expected in various situations for each of the six scenarios. These estimates have been applied to accident data for Great Britain and the resulting estimates of accident reductions are given in the table below.

Estimates of the possible accident reductions from EVSC

System Status	Speed Limit System	Low Estimate (%)	Best Estimate (%)	High Estimate (%)
Advisory	Fixed	2.3	9.0	20.9
	Variable	2.3	10.0	21.5
	Dynamic	3.0	12.0	26.5
Mandatory	Fixed	11.0	20.0	31.0
	Variable	12.0	22.0	32.0
	Dynamic	19.3	35.0	49.0
Percentages based upon a total of 230,376 reported injury accidents in 1995				

Monetary valuations of the expected accident reductions have been calculated using the average accident costs for 1995 and these have then been projected into the future. The predicted accident savings have been established for three growth scenarios.

Firstly a projection of the current accident rate and level of travel demand, and then two scenarios which use an extrapolation of the current decreasing trend in accident rates, together with high and low estimates of travel demand. Of these the middle option, that based upon a decreasing accident rate and a higher level of travel demand has been considered as the base case for the analysis.

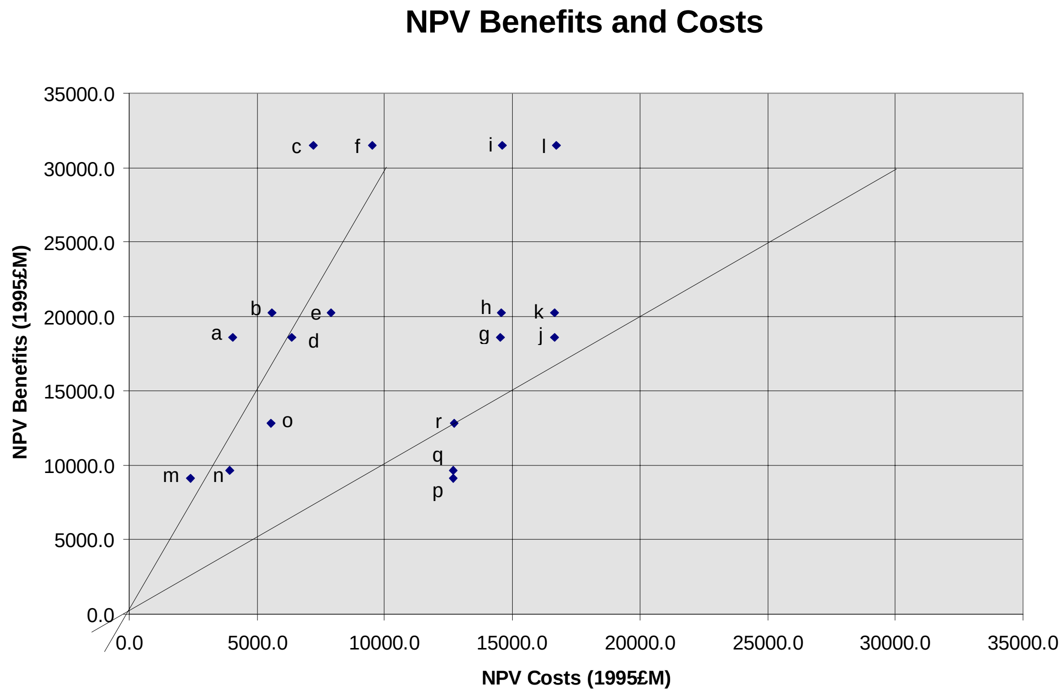
7.2 COSTS

On the cost side three primary options have been identified: a *Mandatory System* with a compulsory application of speed limits which are supplied to the vehicle speed control system; an *Advisory System* in which speed advice is provided to the driver who retains vehicle speed control and a *Driver Selection System* in which the driver obtains speed limit data from road signs but may choose to activate the vehicle control system to keep the vehicle at, or below, the required speed. An additional consideration for the Mandatory system was whether or not active retardation, i.e. use of the braking system to actively reduce speed when a vehicle passes into a lower speed limit, is included.

It must be recognised that the prediction of the future, mass production, costs of what is a developing technology is difficult. Throughout the cost analysis, elements of the system have been assigned generic products types. The generic costs have then been estimated for a 1995 base and a 2010 future cost. All costs are however expressed in 1995 £ values.

The options costed are clearly divided into two groups based upon the information supply system. For an autonomous system, termed a CD-ROM system, in which the speed data is help on a digital map inside the vehicle, the major cost is an in-vehicle costs, which would be borne by the vehicle owners. For a beacon based system, the major costs are in developing the beacon network and would be most likely borne by the public sector. Although the latter has a high initial cost it would be cheaper in the longer run. The principal reason for this finding is related to the balance of in-vehicle costs and the number of new vehicles registered each year.

Having considered both the benefits and the costs of the various implementation scenarios, the benefit cost ratio has been established for each option. The figure below shows the Net Present Value (NPV) Benefits and Costs for the various alternatives. The lower diagonal line indicates a 1:1 Benefit/Cost ratio: systems above that line have greater benefit than cost. The upper diagonal indicates a 3:1 Benefit/Cost ratio: systems above that line exceed a 3:1 B/C. It is clear from the analysis that an economically attractive system of EVSC is highly likely to be developed. Indeed more than half of the systems investigated have benefit cost ratios in excess of 2.0 and at least five systems have benefit cost ratios greater than 3.0.



Key:

	MANDATORY					
	Passive Retardation			Active Retardation		
	Fixed	Variable	Dynamic	Fixed	Variable	Dynamic
Beacon	**a**	**b**	**c**	**d**	**e**	**f**
CD-ROM	**g**	**h**	**i**	**j**	**k**	**l**
	ADVISORY SYSTEM (no retardation system)					
Beacon	**m**	**n**	**o**			
CD-ROM	**p**	**q**	**r**			

In all studies of this type assumptions about the level of future year travel play a significant part in the determination of the benefit cost rations. The quoted benefit-cost ratios assume that, even in the absence of EVSC, a significant reduction will occur in current accident rates albeit combined with increasing travel demand. This reduces the benefits of the scheme below that which would result from a simple projection of current levels of vehicle ownership and the current accident rate. A simple projection of the status quo would increase the benefit and therefore the B/C by 50%. If the accident reductions are applied to an accident base that reflects a lower level of travel, the benefits are reduced by 25%.

The more economically attractive systems have a lower in-vehicle cost and a higher infrastructure costs. However, it is important to remember the distinction between those systems that require high infrastructure investment and therefore funding by central government and those that may be implemented progressively with much of the cost being incorporated into new vehicle purchases.

It has not been possible to calculate a B/C for the Driver Selection System. Under this system speed information is received from road signs, as at present, and drivers input this manually into a vehicle control system. Given that the driver selection system need only achieve 52% of the benefits of a purely advisory system or 26% of the benefits of the mandatory system to achieve a B/C exceeding 2.5 it is potentially a very attractive system. The key issue is the level of compliance, and given that such a system is potentially attractive this will required further research aimed at assessing the likelihood of drivers activating the system. Systems that include active retardation, those where the vehicles braking system is used to actively reduce speed when a vehicle passes into a lower speed limit, have lower B/Cs than those using passive retardation which is based on the natural deceleration of engine braking. This is because of the higher in-vehicle equipment costs associated with active retardation and the assumption that the full benefits of mandatory speed control will accrue to a system which does not have an active braking system. This remains untested and in view of the significant effect that this assumption may have on the choice of system, further research should be undertaken on this issue.

Although the recommendations have been based upon a “best estimate” of the accident reductions the sensitivity analysis shows extreme variations between the low and high estimates for accident reductions. Even though the variations are high a number of systems produce attractive economic returns even when the lowest estimates of accident reduction are considered. Further research into the behavioural aspects of EVSC are expected to refine the variation in accident reductions. The more traditional forms of safety measures, blackspot studies and the associated accident reduction projects, generate very high benefits and are typically low cost. Such projects do, by definition, concentrate on addressing problems at sites with severe accident histories. Not surprisingly there is a trend for decreasing benefits with larger schemes. In comparison EVSC will address widespread random accidents which are not the target of the traditional schemes. It should be noted that the general decrease in accident rate has been used when calculating the benefits of EVSC. This downward trend reflects the effectiveness not only of the traditional accident reduction programmes but also of enforcement and road safety education programmes.

The overall conclusion is that very large benefits in terms of accident reduction are likely to be generated by EVSC — the impact may well be larger than that of any other single intervention. One or more systems are likely to produce benefit cost ratios that are in excess of 3.0. The final decision on a recommended system will depend upon the cost of the technology used to implement EVSC. Given the sensitivity of any recommendation to the cost estimates, further refinement of these will be necessary, particularly as the technologies to be used become clearer and information on their cost improves.

8. DELIVERABLE 7: LEGAL IMPLICATIONS OF EXTERNAL VEHICLE SPEED CONTROL

This report examines the possible function of EVSC from the perspective of the legal issues that may be raised to introduce and regulate the technology as well as the important consequences to post accident litigation. It assumes that the main goal in the introduction of new vehicle technology is to offer better assistance to driver's to safely and efficiently control their vehicle in an increasingly complex traffic environment. This goal may also apply to External Vehicle Speed Control (EVSC).

The report concludes that the legal and liability issues associated with transport telematics systems in general, and EVSC in particular are unclear. There is little experience of how advanced vehicle control systems will be viewed at either a regulatory or post-accident litigation stage. In addition, at this stage the full functionality of EVSC remains undefined so only interim inferences can be made towards the areas of potential concern. However an assessment of the generic factors affecting the liability between manufactures, legislators and users has been made and this suggests that the complexity of liability in respect to a *mandatory automatic* speed control system would be at a higher level than that with *advisory* systems. Development of systems to provide either “level” of speed control would however have to address how the system software/hardware development programmes are directed, by standards or regulations, and performed within manufacturing industry.

The complexity and novel nature of some aspects of this new technology may also bring a wider range of issues forward that may potentially prove to be a barrier to implementation. These so called Advanced Driver Assistance Systems (ADAS) have been intended to **assist** the driver in controlling the vehicle in the traffic environment. Many of these systems would potentially also have some level of **intervention** with the driver's direct control of the vehicle's "performance". An example of such a system is Autonomous Cruise Control (ACC) which would control speed and headway of a vehicle by sensing the presence of other road vehicles and responding appropriately. The availability of such technological options that may alter the interaction and "ownership" of control between the driver and the vehicle have also raised a number of questions about how the performance of such systems may be potentially viewed in future real world use and potentially in post-accident litigation.

These questions may most appropriately raise the issue of who is most liable for an accident, the driver or the vehicle manufacturer? As the technology platforms established by the ADAS type of applications becomes better known and nearer to market a number of additional control functions can be conceived to utilise the technology. One of these is the concept of EVSC where a vehicle has on-board information about the local SL and may have the vehicle's control system limit the maximum speed of that vehicle to that SL. Such a function may therefore also have an effect on the driver's range of control of vehicle performance whilst driving and may therefore also have associated issues regarding legality and liability. It was therefore appropriate to assess what is currently understood about the range and complexities of these issues and identify how they may affect EVSC.

The development of ATT systems creates a completely new area to which there are few coherent policies, institutions or legal frameworks defined. At this stage of development there is therefore a degree of uncertainty about how such systems will be viewed when they reach the possibility of real world application. As a result there is considerable activity to establish early national and international standards, evaluation methods and design guidelines to be applied to ATT systems. These are attempting to generically establish a baseline from which ATT can be designed and developed. However such activities can only be based on limited initial experience with early prototype applications. As there is not yet any substantial real world experience in how such systems will be used and abused by the general driving population there is questionable validity in evaluating the “safety of systems that are not yet fully established. However if some consensus view is not formed on what is acceptable in the performance of ATT system then it raises question about whether such systems can be released to market.

Such consensus views are often driven by the development of appropriate international standards. Such processes at European (e.g. CEN) or International (e.g. ISO) level are frequently lengthy and complex but offer a formal consultation process on the development of an agreed workplan to establish positions on prioritised aspects of ATT design. Such activities may initially define voluntary standards, i.e. ones that may or may not be used by manufacturers. However as the standards process effectively defines an international position they are often frequently accepted as a *de facto* requirement. Indeed they often provide the foundation for a subsequent *de jure* obligation.

The need for such a consensus of opinions between authorities and industries to develop such procedures and standards is important to bring forward early implementation of beneficial technology. As indicated above this may in turn potentially affect the priority given to any laws or regulations that may have to be developed to control and direct the introduction of such systems. Such legal requirements may therefore directly influence the development, emergence and performance of the systems themselves. This may be seen as a potential extension, or modification, to existing regulations for traffic and vehicle construction and use. When a more detailed specification for EVSC is available the relevance of these regulatory requirements will have to be re-evaluated.

The adoption of legal requirements may remove some of the uncertainties regarding ATT however it may raise the liability issue with those that issue the requirements. Experience in the automotive engineering industry over the last two decades has shown a growing emphasis for the need to consider liability. The experience for vehicle manufacturers in the North American market has shown that their liability with regard to the vehicle design can be, and is, tested with great regularity. New technologies such as ADAS are also likely to have an equal level of legal enquiry in the future as there has been for "conventional" vehicles produced in the past. This problem of defining "if" and "where" legal liability occurs should any problems be encountered within an ATT application may therefore be a considerable deterrent to potential investors and users. These questions concerning liability will also come most to the fore when considering legal actions occurring after a road traffic accident. In such post-accident litigation the liability of all parties thought to be of relevance in the manufacture, operation and ownership of that vehicle and other individuals and vehicles involved.

The adoption of ADAS type systems will therefore have to consider the ramifications of these concerns. In an ERTICO working group on the implementation of generic ADAS functions it was acknowledged that there are a number of legal and liability questions that are current. The draft ERTICO ADAS report from this working group describes these questions as:

- Criteria for assessment of potential damages resulting from ADAS usage, e.g. allocation of a damage to either intention or carelessness of users.
- Inclusion of new regulations for drivers' behaviour into highway codes determining their responsibility, based on global consideration of the state of the art in science and technology, e.g. findings in psychological aspects of perception and behaviour
- Clarification of product liability (software applications)
- Regulations for situations resulting from system failure behaviour of ADAS: regulations should define responsibilities in situations such as system malfunctioning, failure or system deactivated
- Regulations for mandatory installation of crash-recorders in ADAS equipped vehicles: advantages are clear, such as clarification of responsibilities for an accident, but also disadvantages, e.g. possibility of fines based on the registered information
- Regulations concerning responsibility of driver versus increasing level of automation.

This analysis indicates that the introduction of new vehicle construction and use type ***regulation*** is a key factor in addressing some of the problems in legal and liability terms to ADAS and, by definition, EVSC.

The practical engineering process of specifying and developing an EVSC is also very relevant to the this issue. The design of systems that are “as safe as necessary” was described. This philosophy has been developed in the draft standard IEC 1508 “Functional Safety of Electrical, Electronic and Programmable Electronic Systems” which proposes the use of a Safety Life-Cycle which is added to the normal development life-cycle. The implications and applicability of such a philosophy to an EVSC development was also described

Legal and Liability issues that remain to be evaluated in more detail in respect to EVSC are:

- Relevant liabilities of parties in future EVSC implementation scenarios.
- Enforcement, particular with respect to the expected accuracy of EVSC equipment.
- Definition of "fail-safe" conditions for EVSC.
- Determination of any negative on drivers, such as de-skilling and risk compensatory behaviour.

9. PHASE II OF THE PROJECT

Phase II of the project's work is now under way. One major piece of work in this phase will be to carry out studies of driver behaviour with speed-limited vehicles, both in the laboratory, on a driving simulator, and on real roads. The drives will cover a variety of both urban and rural roads and the focus in the data collection will be on driver speed, errors and interaction with other road users. Other work in Phase II will use simulation modelling to look at the potential side effects of the system in terms of effects on traffic (congestion, delay), fuel consumption, emissions and travel time. Finally, further work will be carried out on the technical aspects of EVSC implementation, looking at how an EVSC system might be specified in terms of performance requirements and what kind of timetable might be feasible for introduction of the system into various categories of vehicle. Phase II will end in May 1999.