External Vehicle Speed Control

Executive Summary of Project Results

July 2000

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: Executive Summary of Project Results
Author(s)	Oliver Carsten and Mark Fowkes
Editor	Oliver Carsten
Reference Number	EVSC–Exec3
Version Number	1.1
Date	12 July 2000
Distribution	Public
Availability	Unrestricted
File	C:\External Vehicle Speed Control\Deliverables\Executive Summary of Project Results.doc
Authorised	O.M.J. Carsten
Signature	O.M.J.
© Institute for Transport Studies, University of Leeds	

Disclaimer

The External Vehicle Speed Control project has been carried out under contract with the Department of Environment, Transport and the Regions (DETR) by a consortium comprising the University of Leeds and the Motor Industry Research association (MIRA). The opinions, findings and conclusions expressed in this Executive Summary are those of the research project alone and do not necessarily reflect those of DETR or of any organisation involved in the project. The recommendations made here do not represent government policy and no political decisions have been made to move ahead with the implementation of EVSC. The findings of the EVSC project will, it is hoped, make a contribution to a rational debate about the potential of EVSC. EVSC has the potential to bring about a very considerable accident reduction, but that potential can only be realised, if in the end there is public support for the introduction of EVSC.

Table of Contents

Glossary

ACC	Adaptive Cruise Control — variant of cruise control that has the extra capability of maintaining a set time headway
Advisory EVSC	A variant of EVSC that provides information to the driver on speed limits, but without the capability to link this information automatically to the vehicle controls
ADAS	Advanced Driver Assistance System(s) — system using information and communications technology to provide driver support in the form of advice, warnings or assistance in vehicle control
DGPS	Differential Global Positioning System — the accuracy of normal GPS is enhanced with a broadcast correction signal. This was vital for many civil applications until Selective Availability (see GPS) was turned off.
Driver Select EVSC	A variant of EVSC that allows the driver to enable and disable control by the vehicle of maximum speed
Dynamic EVSC	EVSC system enhanced to provide lower speed limits in response to current conditions of the road network (it is assumed that the system will also have the capability of Variable EVSC)
ECU	Electronic Control Unit
EVSC	External Vehicle Speed Control: a system that provides the vehicle with information on the speed limit for the road currently being driven on and which provides the capability for automatic limitation of vehicle top speed to the current limit.
Fixed EVSC	EVSC system with knowledge of posted speed limits
GPS	Global Positioning System — the U.S. satellite system for global navigation, which until recently because of deliberate error for civilian use (“Selective Availability”) provided an accuracy of approximately 100–200m.
HMI	Human Machine Interface
ITS	Intelligent Transport System
Mandatory EVSC	A variant of EVSC in which the vehicle maximum speed is limited automatically
Variable EVSC	Fixed EVSC enhanced to provide slower speed limits at particular geographic points in the road network

INTRODUCTION

The aim of the External Vehicle Speed Control (EVSC) project has been to review a broad range of factors related to the possible introduction of an automatic system to limit the top speed of road vehicles. No policy decision has been made on whether or not to move ahead with the implementation of such a system for the vehicles on Britain's roads. The project is intended as a piece of research to provide information on the likely benefits and costs associated with the variants of a speed-limiting system, on driver behaviour while using the system, on the network side effects of limiting vehicle maximum speed and on possible implementation scenarios.

The research into EVSC is in line with the view expressed in the White Paper of July 1998 "A New Deal for Transport: Better for Everyone" that the capabilities of technology are changing very rapidly. The White Paper, in discussing technologies for enforcement, make specific reference to the potential for linking the technologies used in adaptive cruise control to geographic information systems in order to make speed limits self-enforcing.

This Executive Summary summarises the results of all three phases of the project.[1] Phase I 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. The technical design of the system including communications, system logic and the control mechanisms
4. Acceptability
5. Implementation scenarios, predicted safety benefits and cost-benefit analysis

Phase II was the main research phase of the project. Its major work was concerned with:
1. Design of a prototype system-user interface (HMI)
2. Driving simulator experiments
3. On-road trials
4. Simulation modelling to predict network impacts of EVSC
5. Assessment of implications of EVSC for the future UK vehicle fleet
6. Review of preferred approach to implementation developed in Phase I
7. Performance specification for EVSC

In Phase III, the project work was reviewed and a proposed strategy for implementing EVSC was prepared. In preparing the strategy which is outlined in the Final Report, the predictions of the safety benefits of EVSC that had been made in Phase I were revised as was the cost-benefit analysis. Other work in Phase III covered how EVSC could be put into mass production.

In addition to the work items specific to each phase, work was also carried out throughout the project to examine the legal implications of EVSC and to compile information on parallel and relevant work in the UK and elsewhere in Europe.

---

[1] There are separate Executive Summaries covering Phase I (issued June 1998) and Phase II (issued January 2000).

PART ONE: EVSC TYPOLOGY

An EVSC system can be characterised by how *intervening* (or permissive) it is. Here the standard variants are:

1. Advisory — display the speed limit and remind the driver of changes in the speed limit;
2. Voluntary ("Driver-Select") — allow the driver to enable and disable control by the vehicle of maximum speed;
3. Mandatory — the vehicle is limited at all times.

An additional possible variant between (2) and (3) is a mandatory system which allows excursions allowed, e.g. for overtaking. Such excursions could be limited in number per unit of time or frequency per length of road.

Another dimension for differentiating EVSC systems is that of the *currency* of the speed limits themselves. Here the major typology used in the project has been:

1. Fixed — the vehicle is informed of the posted speed limits;
2. Variable — the vehicle is additionally informed of certain locations in the network where a lower speed limit is implemented. Examples could include around pedestrian crossings or the approach to sharp horizontal curves. With a Variable system, the speed limits are current spatially.
3. Dynamic — additional lower speed limits are implemented because of network or weather conditions, to slow traffic in fog, on slippery roads, around major incidents, outside a school at drop-off and pick-up times, etc. With a Dynamic system, speed limits are current temporally.

A third dimension (one that only applies to Voluntary and Mandatory EVSC) is how the EVSC control is applied. To date, the speed-limited cars built outside the UK have tended to use a haptic throttle, i.e. a throttle pedal that gets more stiff as the excursion from the speed limit increases, and not to apply any braking. The project has implemented EVSC in a vehicle using a combination of "dead throttle" and active braking. The initial retardation is achieved by intervening between accelerator position and engine control (through a combination of ignition retardation and fuel starvation). Additionally, a small amount of braking force is applied when the vehicle is determined to be a certain amount over the set maximum. By locating the onset of the retardation, *before* passing into a lower speed zone, the vehicle can be ensured to be in compliance with legal speeds at all locations.

PART TWO: ACCEPTANCE

In the first phase of the project, 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. Further work on the acceptance of EVSC was carried out with the subjects in the user trials.

1. HOUSEHOLD SURVEY

Stated Preference (SP) surveys present those surveyed with hypothetical alternatives. The preferences stated by the respondents amongst the alternatives provide information on the relative importance of the attributes underlying the choices that are presented. The survey conducted here 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 respondents were split on gender and status as follows:

	Drivers	Residents	Total
Male	46	32	78
Female	42	39	81
Total	88	71	159

Prior to the SP questions, the respondents were asked a number of questions on 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.

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. The three focus groups were composed from different combinations of the following:

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

A short presentation on the concept of EVSC initiated the sessions, after which, a general discussion was encouraged on the benefits, costs and acceptability of EVSC.

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’. Publicity campaigns and increased road safety education in the school curriculum were seen as better ways of addressing the poor attitudes underlying accidents.

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.

3. ACCEPTANCE STUDIES DURING USER TRIALS

Driver acceptance of the systems was measured using an acceptability scale which allowed drivers to express opinions about the variants of EVSC tested in terms of “usefulness” and “satisfaction”. Data was collected before the first drive and after each drive. The dimension “useful” can perhaps be interpreted as indicating the extent to which the system is rated as socially useful, reflecting the impact of the system on safety. “Satisfaction” is clearly related to how much the driver likes the system in the sense of how it assists in fulfilling the driver’s personal goals.

In the simulator studies the Mandatory variant was rated more “useful” than the Driver Select variant with no real change with familiarity with the system. Before the first drive, the “satisfaction” rating was slightly negative for Driver Select EVSC and slightly positive for Mandatory EVSC. After use, acceptability on this dimension increased for those who experienced the Driver Select system, while for those who used the Mandatory system it increased and then decreased to the original level.

In the real road study, the drivers generally believed the Driver Select system to be more “useful” than the Mandatory system. After driving with the Mandatory system for the first time, the scores on this dimension rose, but subsequently fell after their second drive. The Driver Select system demonstrated a similar pattern. In terms of “satisfaction”, the rating was very negative before the first drive for Mandatory EVSC and somewhat negative for Driver Select EVSC. The negative ratings for both variants tended to decrease after each use of the system.

These findings can be interpreted as showing that the drivers are generally more positive about the social aspects than the personal aspects. Not surprisingly, they prefer the voluntary system which leaves them in full control of speed choice to the mandatory system. In general, the scores tended to improve with familiarity.

PART THREE: USER TRIALS

1. EXPERIMENTAL APPROACH

The objectives of the user trials were to:

- Assess the variants of EVSC
- Cover all the common classes of road
- Study driver adaptation over time (with repeated use)
- Measure safety critical behaviour
- Evaluate workload and acceptability

The work was carried out using a driving simulator and a specially modified car on real roads. The two types of test were intended to complement each other. In the simulator, each driver has the same experience in terms of surrounding traffic, weather etc. It is also possible to create scripted scenarios to examine, for example car following, and critical events. However, this control of the situation, comes at some loss of naturalness. Hence the need to carry out on-road trials. The latter also permitted experience to be gained with the enabling technologies for EVSC.

2. HMI USED AND VERSIONS OF EVSC

The Human Machine Interface (HMI) for the system employed a visual display on the dashboard, which showed on the left side the speed limit and on the right side the speed to which the car was limited if the limiter function was enabled. This display, as it was implemented in the simulator, is pictured in Figure 1. At each speed limit change on the route, the speed limit on the left changed and there was an auditory prompt. In addition to the display, the steering wheel was fitted with a green and a red button. How the system then behaved depended on which of versions of EVSC was in use. There were two major versions of EVSC used in this project. The first version was a voluntary system, termed ***"Driver Select"***. Here drivers had the option of whether or not to be limited to the advised speed limit. At each change the driver had three choices:

- Firstly, if the driver wished to engage the system, and thereby be limited to the maximum speed as shown on the display, he/she pressed the green button on the steering wheel.
- Secondly, if the driver chose to override the system, and thus be free to travel at any speed, he/she could at any time press the red button on the steering wheel. Use of the red button disengaged the speed limiter and placed the system in standby mode (information on the speed limit still

Figure 1: Speed limit display

appeared on the screen).

- Thirdly, the driver could choose to ignore the auditory prompt. If the driver ignored the prompt, he/she was alerted by a second auditory signal. If the driver continued to ignore this, after 4 seconds the system reverted to standby mode, whereby no control is exerted.

The Driver Select system could be engaged and disengaged at any point on the experimental drive (not just at the speed limit changes), by using the green and red buttons. Figure 2 shows the interface in the modified car.

Figure 2: In-vehicle interface

With the alternative ***Mandatory*** version of the system, the maximum speed of the car was permanently limited to the posted speed limit of the road. Thus the driver was never able to exceed the speed limit. The system operated is such a way as to slow the vehicle down when necessary in advance of a speed sign so that the vehicle was in compliance when entering a slower speed zone.

Finally, there was an additional version of the mandatory system, the ***Variable*** system. This was only implemented in the driving simulator. It had the extra functionality of lowering the speed further on substandard curves and around pedestrian crossings. Drivers were informed of the reason for this additional reduction of speed in advance via the in-car display.

3. SIMULATOR STUDY

The aim here was to evaluate behaviour with the three EVSC systems (Driver Select, Mandatory and Variable) in a controlled environment. The simulated road included urban, rural and motorway sections, providing a range of speed limits between 30 and 70 mph. It was 22 miles long. Other cars in the scene provided the opportunity to study overtaking scenarios, gap acceptance tasks and car-following situations. The road environment also featured traffic lights and pelican crossings in order to instigate possible violations; and sub-standard curves were included in both the urban and rural sections. Workload and acceptability were also monitored. Forty members of the public attended the simulator on four separate occasions. All drove the car once without an EVSC system. Thirty then drove three times with one version of the system (10 with the Driver Select version, 10 with the Mandatory one, and 10 with the Mandatory plus Variable one). The other 10 participants drove a further three times with the system off, to provide a baseline. There were thus 160 drives in all.

The results suggest that the EVSC systems had little impact on mean speeds, but reduced maximum speeds. The effects of the EVSC systems were most prominent at specific locations, such as village entry. Figure 3 shows the speed profiles across systems for one village entry.

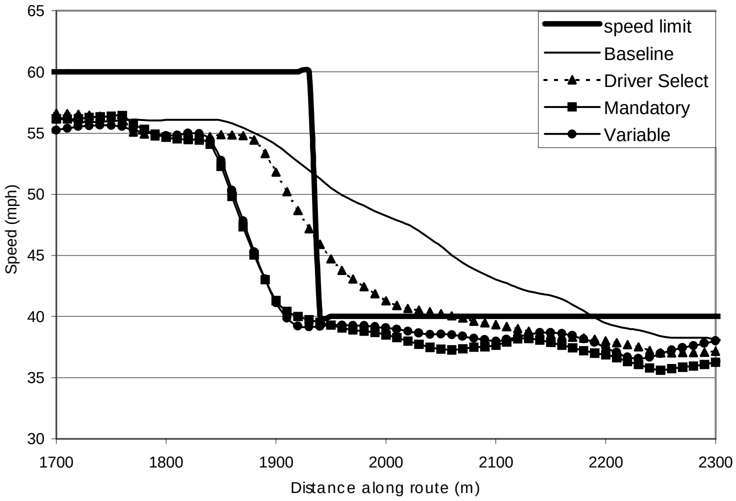

Figure 3: Speed profiles for entry into a village

Table 1 shows maximum speeds in one of the villages on the route. From Table 1, it can be seen that with Mandatory EVSC maximum speed was substantially lower, as compared both with the initial run with no EVSC and with the speeds in Runs 2–4 of the drivers in the baseline condition. The same effect is found in the Variable situation (the Variable system operates here like the Mandatory one, but was operational on one curve). With the Driver Select system, maximum speeds are in between those with the Mandatory system and those with no EVSC.

Table 1: Maximum speed in 30 mph village (averaged across drivers)

SYSTEM	Run 1 (baseline)	Run 2	Run 3	Run 4
Baseline	33.52	35.21	34.12	35.21
Driver Select	33.24	32.12	32.56	31.27
Mandatory	34.15	29.15	29.56	29.54
Variable	32.58	28.74	29.31	29.07

Note: Shaded cells show drives without EVSC

There were several changes in behaviour noted in the experiment. It was found that, when using an EVSC system, gap acceptance behaviour altered. The mean gaps accepted and the minimum times to collision reduced in size, suggesting that drivers were exhibiting riskier behaviour. Figure 4 shows the results for a left turn with traffic approaching from the right.

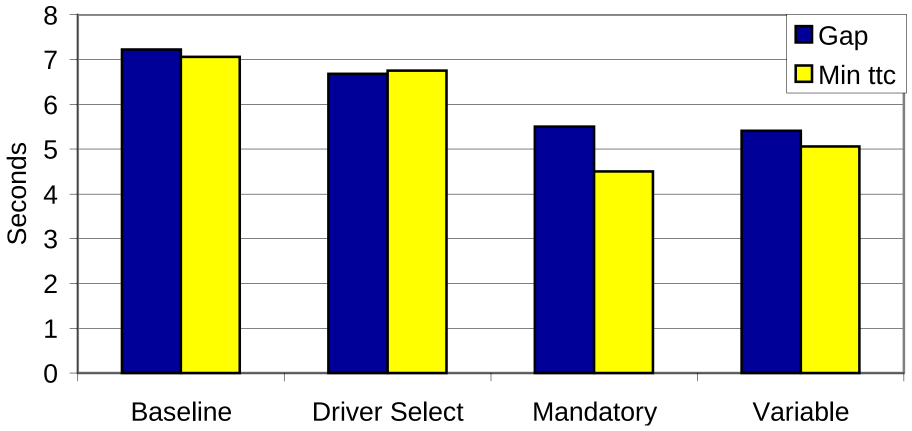

Figure 4: Mean gap accepted and minimum time to collision on left turn merge

There were also observed changes in car following behaviour. Safety-critical close following (less than 1 second) increased in both urban and rural areas. When driving behind a slow moving vehicle (with no opportunity to overtake), drivers using an EVSC system were more likely to want to engage in close following. Figure 5 compares the amount of close following for drivers who experienced the Mandatory system. The figure compares behaviour on Run 1 (no EVSC) with that on Runs 2–4 (with EVSC).

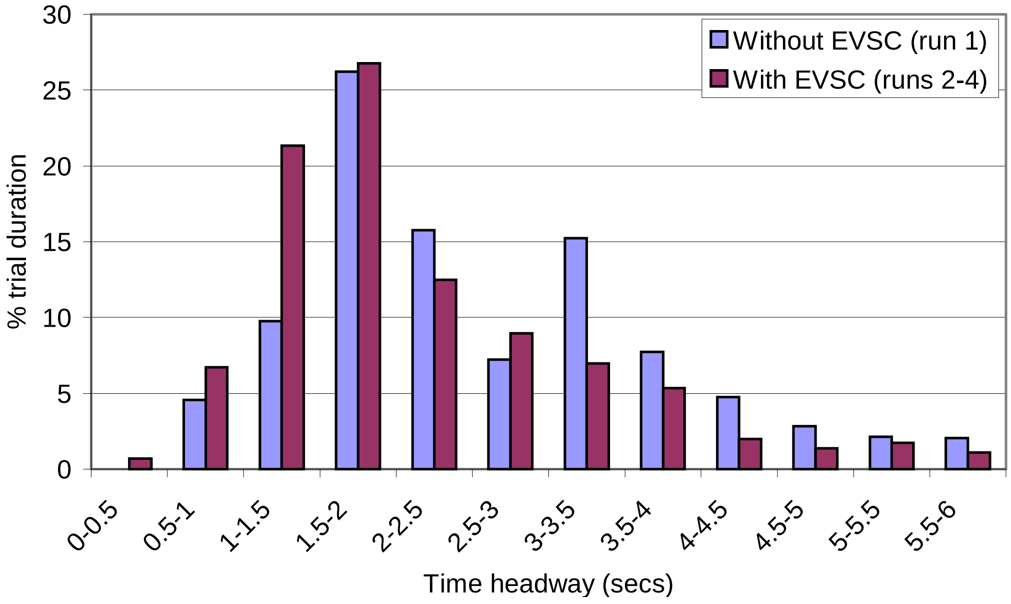

Figure 5: Time headway on urban roads for drivers with Mandatory system

Subjective mental workload scores were obtained and, both time pressure and frustration increased as drivers used the system more and more. This time pressure does not translate into actual loss of time, as there was little change in total journey time for each of the progressive runs. Thus this increased time pressure is only imaginary, not actual. From the acceptability questionnaires, it was found that generally, drivers valued all EVSC systems more highly after having experienced one. The Driver Select system demonstrated the most improvement in acceptability ratings and was the preferred system.

In summary, it can be seen that the experiment confirms the potential benefits of EVSC systems, with reference to reduced maximum speeds and improved speed adaptation in speed limit transition zones. This experiment, however, has highlighted the fact that predictions about safety benefits should take account of the secondary effects that occurred. Such secondary effects, including the propensity to adopt riskier driving behaviours, may not outweigh any benefits gained under speed control, but the possibility of their occurrence should be noted. Further evaluations of EVSC systems should include appropriate methods of gauging the extent of both positive and negative effects of the system, with particular emphasis on observing behaviour in long-term use.

4. ON-ROAD STUDY

This study required drivers to drive a predetermined route in a modified car. The vehicle (pictured in Figure 6) was equipped with two versions of EVSC, Driver Select and Mandatory. Using dGPS, the position of the car could be monitored with an accuracy of about 1m. The position and value of every speed limit change along the test route was stored in a laptop computer. The EVSC software compared the current speed limit with the car’s actual speed. If the car was travelling below the speed limit, it behaved as per a normal car. However, if the speed was above the limit, a signal was sent to a pair of auxiliary ECU’s. These first reduced engine power by retarding the ignition. In order to provide a longer and/or greater reduction in power, the amount of fuel injected into the engine was progressively cut. If the retardation and the fuel cut-off were insufficient, because the car was going down hill for example, the brakes were gently applied to decelerate the car to the speed limit. The maximum deceleration from the EVSC system was in the region of 0.2g.

Figure 6: EVSC car

The test route was selected to include roads of varying speed limits and classes, and was approximately 42 miles in length. Speed limits varied from 30 to 70 mph, and included urban roads with mixed traffic and a high number of pedestrians, rural roads and a motorway section. In total there were 18 speed changes on the test route. The data collected included speed, braking, amount of retardation imposed by the system, and system state. Behavioural observations were made by two in-car observers with regards to driving errors, interaction with other drivers and conflicts. Workload and acceptability were assessed using questionnaires. There were 24 participants in the experiment. They drove on three separate occasions; all drove the car once without an EVSC system; 16 then drove the car two further times with one version of the system (eight with the Driver Select version and eight with the Mandatory one). The other eight participants drove a further two times with the system off, to provide a baseline. There were thus 72 drives in all.

With regard to the Driver Select system, drivers were generally happy to leave the system engaged, but as soon as the opportunity to exceed the speed limit arose, they chose to disengage the system.

Analysis of the data shows that drivers are inclined to switch the system off precisely in the locations where the system would have had the most impact, i.e. the rural villages and urban roads where traffic generally exceeds the speed limit, and that they do deliberately in order to exceed the speed limit. It was also noted that drivers used the system less on their second drive, indicating there may be shifts in behaviour depending on the amount of exposure to the system.

The Mandatory system, as would be expected, had a far greater impact on driver behaviour. Large reductions in maximum speeds were noted on most road sections, especially in urban areas and rural villages, as can be seen from Figure 7. The data shows quite clearly that, in the absence of the EVSC system, the drivers were poor at adapting to low speeds after travelling through a higher speed limit area.

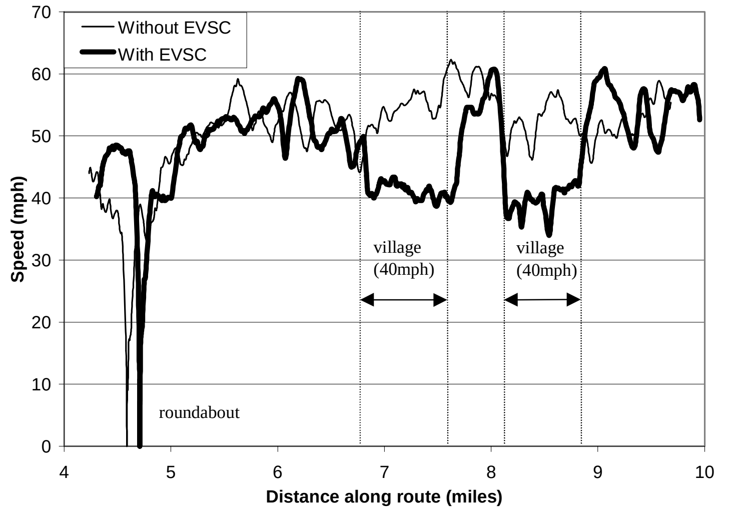

Figure 7: Individual speed profile with Mandatory system

The effect of the EVSC system is also obvious in the overall speed distributions that were measured for each speed limit, as there was a "transformation" of the distribution whereby the top end of the distribution was virtually eliminated by the system and driver speed was more concentrated around the speed limit. This effect can be seen in Figure 8, which shows the changes in the percent of driver time spent at different speeds for a section of 40 mph urban roads. From the same Figure, it can also be seen that there was to be no change in the distribution at the lower end, indicating that drivers were not increasing their speeds in order to regain perceived lost time.

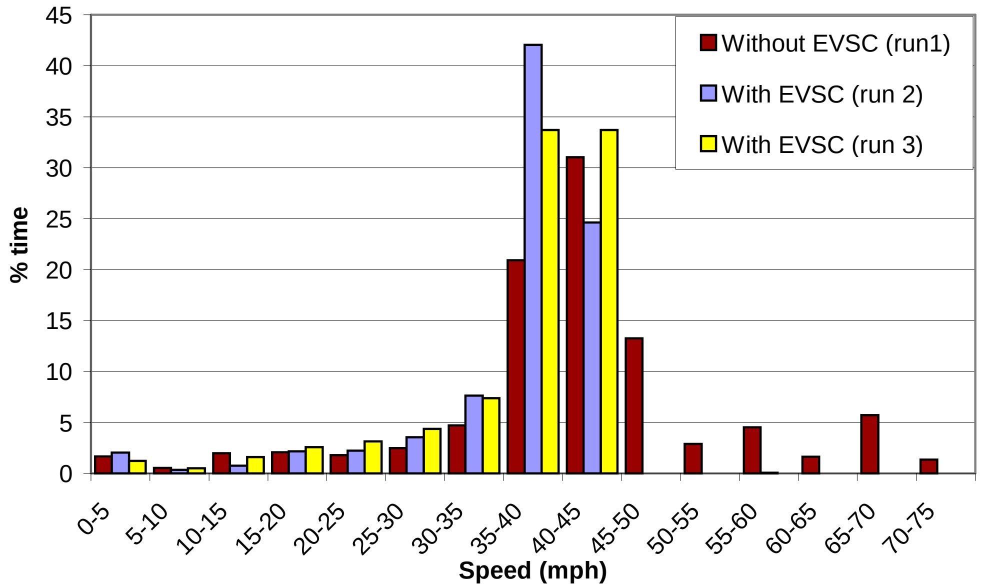

Figure 8: Speed distribution across the 3 trials in urban section (speed limit 40 mph, Mandatory system)

The results from the behavioural observations also indicated that no negative compensatory behaviour was occurring, and in fact some undesirable behaviour such as close following decreased. The finding on close following was largely an artefact of the traffic situation: with other vehicles able to exceed the speed limit, there was a tendency for the vehicles in front to speed away from the EVSC car. In addition, when the total number of conflicts was scored for each system, it was found that the propensity to be involved in a critical situation (whether instigated by the volunteer drivers or other road users) decreased when the system was engaged, indicating improved safety. This can be seen from Figure 9, which shows the conflicts scored by the observers for each run. With EVSC, performance improved as compared with the initial run without EVSC; in the baseline condition with no EVSC on all drives, drivers tended to have more conflicts with increasing familiarity with the route. From the questionnaires, drivers with the Mandatory system felt they paid more attention to the driving task, and as a result were more aware of upcoming hazards. They also reported they felt they had more time to make decisions due to their lowered speed.

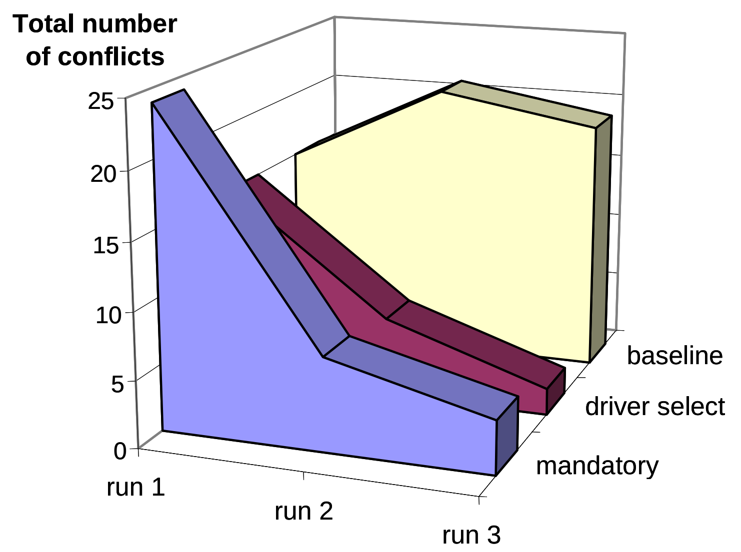

Figure 9: Total number of critical events or conflicts

Subjective rating scales, were completed for each subject. Driver behaviour was seen to improve when the Mandatory system was engaged. These included improvements in use of appropriate speed and following behaviour and less abrupt braking. These are undoubtedly as a result of the reduced speed having secondary impacts on other characteristics of driver behaviour.

Drivers required an adjustment period in order to familiarise themselves with the capabilities of the car when the EVSC system was engaged. Reported mental workload increased initially but then decreased on familiarisation. However in other respects, familiarisation with the system did not change more resistant opinions. For example, drivers were of the opinion that a speed control system would create difficulties when overtaking and prevent acceleration out of danger. These opinions did not diminish with use of the system.

In terms of driver acceptance, the Driver Select system was thought to be more useful than the Mandatory system. Generally, driver opinion about the systems changed little over the course of the trials. The interviews revealed that drivers regarded the Driver Select system as more of a safety system than the Mandatory, and less of a source of frustration. Drivers thought the systems would be particularly useful in built-up area. It must be remembered that the volunteer drivers were driving in traffic that was not speed controlled. Drivers commented that this sometimes made then feel vulnerable, especially when other drivers followed too close behind as a result of not being able to keep up with the traffic flow ahead. When driving with the Mandatory system, other vehicles overtook drivers approximately twice as much as when they drove without. This probably contributed to driver’s feelings of vulnerability and increased frustration. Drivers remarked that the reason they liked the Driver Select system was that they could disengage the system in these sorts of situations and thus overtake or keep up with the traffic, as they desired.

In summary, the Mandatory system trialled in this experiment successfully reduced excessive speed, particularly in areas where drivers are renowned for being poor at adapting their speed, for example in rural villages. Although the use of the Driver Select system was relatively high, drivers were prone to disengage the system at locations where speeding was the norm for the surrounding traffic. This is partly attributable to the fact that drivers preferred to be in control of the system operation and turn it off when they felt vulnerable or under pressure from other drivers. This is a symptom of a mixed traffic environment, and with higher system penetration in the traffic as a whole, drivers may be more inclined to use the system. There were no negative behavioural compensation effects, even though reported time pressure and frustration levels rose when using the system. In fact, some undesirable behaviours and conflicts or critical situations decreased in occurrence when the system was engaged. Although drivers were initially unfavourable towards the Mandatory system, they reported that driving with the system was safer due to enhanced awareness of potential hazards.

5. IMPLICATIONS OF USER TRIALS FOR IMPLEMENTATION

Compliance with or usage of a voluntary EVSC system that interacted with the vehicle controls (i.e. the Driver Select system) was one of the major issues explored in the on-road trials. Generally, the proportion of the time that the driver had the system engaged was reduced from the first drive under EVSC to the second drive. On urban roads, the mean proportion across subject for different road sections during the second drive was in the range between 54% and 78%. On two-lane rural roads, it was in the range between 40% and 55%. On the motorway, the proportion of time with the system engaged was 31%. The observers reported that drivers tended to switch the system off when the traffic conditions gave them the opportunity to speed. In the simulator experiments (Deliverable 11), subjects using the Driver Select system had approximately half the mean speed change of drivers using the Mandatory system in relevant areas, such as the approach to villages. Given these results, and the clear tendency to use the system less with more exposure to it, it has been concluded that an overall compliance of 50% in extended use is a reasonable prediction. **In other words the effectiveness of the Driver Select system is roughly half that of the Mandatory one.** That compliance rate has been used in the accident modelling.

The on-road trials also indicated that there were some difficulties in driving with the Mandatory system when the EVSC car was the only such vehicle on the road. In that situation, drivers sometimes found themselves being left behind by other traffic and were more often overtaken by other vehicles with the system than without the system. This led to feeling of frustration, vulnerability and low levels of satisfaction with the system. **These findings suggest that it would be unwise to implement mandatory EVSC until a significant number of vehicles are equipped.** The threshold at which the EVSC vehicles on the road effectively slow down other traffic was explored in the simulation modelling work.

PART FOUR: SIMULATION MODELLING ON THE NETWORK EFFECTS OF EVSC

Three different road types were modelled: urban, rural and motorway, with two levels of congestion on the urban network (peak and off-peak). Various levels of system penetration into the vehicle fleet were also introduced to the model to investigate the interactions between equipped and non-equipped vehicles. The equipped vehicles were defined as being fitted with the mandatory EVSC system. EVSC penetration was varied for each of the four networks from 0% (the base scenario without EVSC) to 100%, in 10% increments. The measures of effectiveness included journey time, speed distribution, fuel consumption, pollutant emissions and overtaking.

1. JOURNEY TIME

In the urban network, average journey time increased with increasing EVSC penetration. The effect was more significant in the off-peak period than in the morning peak period. The network was congested in the morning peak period, and thus traffic speed was already controlled. Consequently the change in the average journey time as a result of EVSC was small during the peak period. The implementation of EVSC in the rural network had a minimal effect on journey times, with an increase of less than 1% on the average journey time of vehicles between the base scenario and 60% EVSC penetration. At penetration rates above 60%, EVSC does not seem to have a further effect on vehicles' journey time. The effect of EVSC on total journey time on the motorway was small. Between 0% and 70% EVSC penetration, the total travel time varied in a random fashion. At penetration rates above 70% there was a small downward trend in total travel time.

2. SPEED DISTRIBUTION

The effect of EVSC on speed distributions was more significant for the urban networks than for the rural or motorway networks. In the urban network, it was generally found that EVSC was more effective in the off-peak traffic conditions than in high congestion. Whilst EVSC reduced excessive traffic speeds in the network, it did not induce more congestion to the network. Without EVSC, vehicles exceeded the speed limit for approximately 34% of the time in the off-peak urban scenario. In the peak period, this figure was only 20%. In the latter situation, the speeds of the vehicles are controlled already by the congestion. By limiting the excessive traffic speeds to the speed limits, EVSC effectively reduces variation in high travel speeds, which in turn may result in accident reduction. There was little effect of EVSC on the rural and motorway networks.

3. FUEL CONSUMPTION

EVSC reduced fuel consumption particularly in the urban environment. Total fuel consumption gradually decreased with increasing penetration levels of EVSC equipped vehicles. A total 8% reduction in fuel consumption was achieved if the whole fleet of traffic is under EVSC. The same level of benefit is received for both peak and off-peak periods. The reduction in fuel consumption can be explained by the fact that EVSC controls the top speeds of the vehicles, and by doing so, reduces vehicle acceleration and deceleration cycles and keeps the vehicles cruising at slower and more constant speeds. In the rural and the motorway situations, fuel consumption was reduced by 3%–4%.

4. EMISSIONS

In the urban network the total emissions do not vary significantly with levels of EVSC penetration. For the morning peak period, this is primarily due to the lack of any significant change in the traffic characteristics with EVSC implementation. For the off- peak situation, this results from a combination of EVSC implementation and emission characteristics. Generally, emission rates decrease with higher cruising speeds. Opposing this, acceleration and deceleration cycles cause proportionally larger proportions of pollutants to be emitted. Without EVSC, vehicles accelerate and decelerate for longer periods to achieve higher cruising speeds. With EVSC, vehicles will accelerate and decelerate less, to achieve lower cruising speeds. Consequently, these two variables counteract each other, resulting in little variation of total vehicle emission rates with increasing levels of EVSC penetration. In the rural network, emissions increased very slightly with EVSC (in the order of 1%). In the motorway network, there was a decrease in emissions under EVSC. The decrease was most pronounced for carbon monoxide, which showed a 4.2% decrease.

5. OVERTAKING

The implementation of EVSC reduced the number of overtaking manoeuvres in the rural road network. From the base case to 60% penetration of EVSC, overtaking was reduced by approximately 10%, for a likely safety benefit. At higher rates of penetration there was no further reduction in the number of overtaking manoeuvres.

6. SUMMARY OF MODELLING FINDINGS

In general most of the effects of EVSC were found in the urban networks where changes in speed distributions led to slightly longer journey times but lower fuel consumption. There were smaller effects in the rural and motorway networks, except for a decrease in emissions for the latter. As the fleet penetration increases and the EVSC vehicles begin to dominate the traffic flow, non-EVSC vehicles will become more and more constrained. The point at which further increases in the proportion of EVSC vehicles, results in little or no change in highway operating conditions is termed the “saturation penetration”. Table 2 summarises the key results of this work.

Table 2: The impact of Mandatory EVSC on different road networks

Network	Saturation Penetration	Travel Time	Fuel Consumption	Emissions*
Urban Peak	100%	+2.6%	–8.0%	Nil Impact
Urban Off-Peak	100%	+6.4%	–8.5%	Nil Impact
Rural	60%	+0.4%	–3%	+1%
Motorway	0%#	0%#	0%#	Nil Impact

*The emissions predictions are for current vehicles.

#The motorway modelled (part of the M25) was so congested that EVSC had negligible effect.

While the impact of EVSC on travel time and fuel consumption in the urban networks continues to increase through to 100% penetration, the rate of increase declines beyond approximately 60%. **Given the volume of travel for the different road types, the overall point at which the bulk of the benefits of EVSC will be realised is when 60% of vehicles are fitted with EVSC.** It should be noted that these findings are based on the specific cases that were modelled. This caveat is particularly important for the motorway results, where the network selected was a section of the M25, which at times is subject to considerable congestion.

PART FIVE: SYSTEM ARCHITECTURE

When the project began at the start of 1997, the general assumption was that a future national or European EVSC system would be based on roadside beacons, probably Dedicated Short Range Communication (DSRC) beacons. Once the project got underway, the feasibility of alternative system architectures to provide the same EVSC functionality as the beacon-based approach was discussed. An approach was adopted based on an autonomous architecture in which the vehicle would "know" its location from a GPS-based navigation system and would "know" the speed limit for that location from an on-board digital road map in which the speed limit for each link in the network had been encoded. A similar path has also been pursued in Sweden and the Netherlands. This development is not all that surprising in view of the fact that developments in telematics technologies are widely known. There has been a clear development path in navigation and route guidance system technology away from mainly infrastructure based concepts to the much more autonomous systems now on the market. This tendency to migrate from rather centralised to mainly autonomous systems would appear to be a general trend in the development of Intelligent Transport Systems, motivated partly by the falling cost of on-board databases and on-board intelligence and partly by a reluctance on the part of public authorities to commit large-scale investment for the deployment of new systems.

The autonomous architecture is the one that was been implemented in the UK project test vehicle, albeit in simplified form. This vehicle used:

- a differential GPS (dGPS) providing high accuracy (of the order of ±1m while moving) and update of the correction factor once per second;
- a simple digital road map employing unidirectional "virtual" beacons whose radius (zone of influence) can be varied.

The UK vehicle proved to be a hugely successful demonstrator of this autonomous EVSC concept. Speedy implementation of routes for both experimental investigation and demonstration was possible because there were no infrastructure requirements. In addition the vehicle performed with a very high degree of reliability and repeatability throughout the on-road trials, with no failures of the navigation part of the system. This occurred in spite of initial worries about loss of the differential signal in "urban canyons", etc.

The autonomous concept has therefore been shown to be a viable alternative to a beacon-based system, and one that can be reliably implemented with current technology. A number of inferences follow from the autonomous concept:

- Geographic roll-out of EVSC could be immediate. All equipped vehicles would be provided with EVSC support, wherever they were in the network. There would be no need to prefer one type of road over another. Deployment would be rapid, thus eliminating confusion about where EVSC applied. A national road map containing the speed limits for every UK road could be created for comparatively low cost.

- The *public* costs of implementation would be small. The major public cost for the Fixed and Variable versions of EVSC would arise from the creation and maintenance of the speed limit database.
- Benefits would be constrained mainly by the number of EVSC-equipped vehicle in the fleet and by the configuration of EVSC. A small initial public investment would produce a large benefit.
- Changing speed limits would be very cheap. Traffic calming, as for 20 mph zones, would be accomplished with virtually no infrastructure, i.e. little more than a change in the database. The current negative consequences of traffic calming in the form of the noise, fuel consumption and emissions caused by physical measures would be virtually eliminated.
- The EVSC system would function across Europe, provided appropriate digital road maps were available.
- Purchase of an EVSC vehicle would bring with it other “free” ITS systems, such as navigation systems. Another way of looking at this is to conclude that, if most future vehicles are equipped with navigation systems as a matter of course, then the incremental cost of providing EVSC functionality is greatly reduced.
- Based on the experience with the test vehicle, reliability should not be a problem and should approach 100%. Reliability would be enhanced in a production system by map-matching software to compensate for dropouts in the GPS signal.

One major advantage of the autonomous architecture is that many of the sub-systems required to make it operational will be in place in future vehicles or be available for comparatively low cost because they will be mass-market items. This applies particularly to the availability of digital road maps and of GPS-based navigation systems. A digital road map covering every road in the UK is already available on the market, and the road map can be used by navigation systems to give turn-by-turn directions. GPS is likely to be supplemented and enhanced with the European Galileo system, scheduled to be fully operable by 2008 at the latest and offering considerably greater positioning accuracy than current GPS. For Galileo, it is planned to offer a higher-level service class on a subscription basis.

PART SIX: LEGAL ISSUES

The concept of EVSC described here also requires consideration from a legal perspective. There will need to be legal requirements put in place if EVSC is mandated as a fitment to future vehicles. There may also need to be legal requirements placed upon drivers to use and maintain such a function when fitted. There may need to be technical specification and performance requirements detailed to define what EVSC is, and how it should operate and be activated. It is therefore useful to outline some of the legal issues that may be raised by the concept of EVSC and other similar new vehicle control functions under development.

The major vehicle manufacturers have been developing prototypes for Advanced Driver Assistance Systems (ADAS) over the last decade. Many of these systems would potentially also have some level of **intervention** with the driver's direct control of the vehicle's “performance”. The concept of EVSC as investigated in this project has some close similarities to these ADAS systems from both a technological and a legal perspective. It is therefore useful to review how the legal impact of such ADAS has been assessed.

Adaptive Cruise Control (ACC) is the state-of-the-art in ADAS currently on the market and will lead to a range of ADAS with increasingly more complex functions. These ADAS may alter the interaction and “ownership” of control between the *driver* and the *vehicle* and therefore raise some complex issues with regard to how the performance of such systems may be regulated to avoid any negative impacts in future real world use. There are also questions concerning how such systems are designed, developed and evaluated before market introduction to ensure that they are “safe”. Finally, there are concerns as to how ADAS functions will be treated in future post-accident litigation where their operational effectiveness and effect on driver behaviour will be questioned. These questions may raise the issue of who is most liable for any accident, the driver or the vehicle manufacturer. EVSC, in at least some forms and circumstances, will limit the driver’s ability to determine the vehicle’s performance whilst driving. Therefore it may also have associated issues regarding legality in manufacture and use and regarding liability in use and post-accident litigation.

Currently liabilities for vehicle accidents lie mainly with the drivers of the vehicles and any personal liability claims are made through their individual vehicle insurances. When ADAS applications enter the commercial market and systems potentially have greater “responsibility”, there may be a shift in the balance of liability from the owner/driver to the vehicle manufacturers. If a component part of that functionality is provided by the infrastructure then the roadway owners may also be implicated.

The concept of EVSC as a specific future ADAS implies the involvement of the following participants:

- Government bodies to introduce regulatory/legislative requirements for EVSC
- Manufacturers to provide sub-systems and functions to enact
- Suppliers to provide data and database services to facilitate EVSC functions
- Local authorities to provide support to national EVSC requirements
- Maintenance providers to support on-going development of EVSC infrastructure

Each of these participants' sectors may be seen to have a role in liability of a failure of EVSC in the event of some post accident litigation where the relative liability of each participant was brought into question. The relationship between actors and the contractual agreements into which they entered would be a subject of enquiry in such an investigation. It is clear that the implementation of different levels of functionality relating to EVSC in future may potentially have to take into account a number of current regulatory requirements so that an EVSC vehicle, and its sub-systems, can be approved. It is also clear that there may be conflicts with current requirements and amendments, or new regulations may be required to facilitate EVSC implementation and deployment. To review the potential impact of this, an attempt to formally classify different levels of EVSC functionality has been made.

It has already been noted that there may be different "levels" of EVSC. This ranges from simple presentation of speed limit information to the driver within the vehicle to advanced forms where dynamic modification of speed limiting can be introduced to support adaptation to local traffic and environmental conditions. Different levels of functionality would have different technological bases, different operational impacts on the driver and his task, and different issues raised in relation to legal introduction of the "levels". This may place new or different responsibilities on the individuals and organisations involved. This range of participants may include:

- the driver/vehicle owner,
- the road/infrastructure owner
- the national/local government body or agency responsible for providing SL information
- a sub-contractor/intervening organisation who may be working for the government
- the police/enforcement agency
- commercial information organisations

The introduction of amendments to vehicle construction, use, and type approval requirements is a key factor in addressing some of the problems in legal and liability terms to ADAS and, by definition, EVSC. It should also be noted that for EVSC there may also need to be appropriate inspection and enforcement mechanisms in place to assess driver compliance. It is also apparent that the introduction of EVSC functionality within an automotive industry context will require the development of a set of full evaluation and assessment criteria for the EVSC function. EVSC would have to be implemented alongside other aspects of vehicle technology and functionality and it is likely that such a function would have to operate in conjunction with other telematics/ITS applications. Therefore assessment of the integrated function would have to be facilitated. This is particularly relevant to the assessment of the system safety issues related to EVSC.

In summary the legal and liability issues associated with ADAS in general, and EVSC in particular have been reviewed. At this stage in the current project the full functionality of EVSC remains undefined so only interim observations can be made. An assessment of the generic factors affecting the liability between manufactures, legislators and users has been made that suggests that the complexity of liability in respect to a mandatory automatic speed limitation system would be at a higher level than that with advisory systems. 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.

PART SEVEN: IMPLEMENTATION OF EVSC

1. PREDICTION OF ACCIDENT SAVINGS

1.1 Relationship between speed and accidents

In predicting the accidents savings from EVSC, it is vital to note that one cannot isolate a group of accidents as being "speed-related" and then conclude that only this minority of accidents will be affected by intelligent speed limiters. Generally such conclusions have been based on the findings of in-depth accident studies which purport to show that in a proportion of accidents — 10 to 30% — one or other participant can be identified as driving too fast for the situation and that this excessive speed was a contributory factor to the occurrence of the accident. It is not, however, appropriate to infer from such results that only this minority group of accidents will be affected by EVSC, because:

1. The in-depth studies require conclusive evidence that a driver was going at excessive speed before coding speed as a contributory factor.
2. The in-depth studies are subject to investigator preconceptions about what is "excessive" speed. These preconceptions are heavily influenced by the prevailing notions of what is appropriate speed for the road conditions. Over the years, expert opinion about appropriate speeds has been modified generally been downward,.
3. In-depth studies have not generally looked at each accident with the scenario of lower speeds and then asked whether the accident would have been avoided under such circumstances.
4. It is obvious that all accidents are in an important sense "speed-related". With lower speeds, there is greater time to collision, and therefore a greater opportunity to avoid the accident. With lower speeds, drivers have less chance of losing control so that the risk of a single-vehicle accident is greatly reduced and the risk of a loss of control in severe braking or swerving to avoid collision is also greatly reduced.
5. The lowering of driving speed drastically affects collision speeds and thereby the risk of injury, serious injury and fatality since the energy dissipated in a crash goes up with the square of collision speed..

The modelling approach used here to make predictions about the accident savings from the various forms of EVSC has therefore started with the presumption that reduced speeds will directly influence both the probability and the severity of accident occurrence. The relationships used have been derived from the best empirical evidence available, as established by a detailed literature review.

1.2 Predicted accident savings

Table 3 shows the best estimates of the accidents savings, at various levels of accident severity, for the permutations of EVSC. EVSC systems are divided into the broad classes of Advisory, Driver Select, and Mandatory systems. Each broad class can have speed limits in fixed, variable or dynamic forms (where dynamic also includes variable capability). The prediction is that the most powerful and versatile form of EVSC, the Mandatory Dynamic system, will reduce overall injury accidents by 36%, fatal and serious accidents by 48% and fatal accidents by 59%.

Table 3: Best estimates of accident savings by EVSC type and by severity

System Type	Speed Limit Type	Best Estimate of Injury Accident Reduction	Best Estimate of Fatal and Serious Accident Reduction	Best Estimate of Fatal Accident Reduction
Advisory	Fixed	10%	14%	18%
	Variable	10%	14%	19%
	Dynamic	13%	18%	24%
Driver Select	Fixed	10%	15%	19%
	Variable	11%	16%	20%
	Dynamic	18%	26%	32%
Mandatory	Fixed	20%	29%	37%
	Variable	22%	31%	39%
	Dynamic	36%	48%	59%

2. OTHER EFFECTS AND SYSTEM COSTS

2.1 Fuel consumption

Based on the micro-simulation modelling, overall fuel consumption savings with EVSC have been calculated as ranging from 1 to 8%, with an overall figure of 5.5%. The estimated savings by road type in fuel consumption with Mandatory EVSC are shown in Table 4.

Table 4: Annual (1998) fuel savings and calculated travel time increase with Mandatory EVSC

Road Type		Fuel Saving	Increase in Travel Time
Motorway	All	1%	0.0%
Major Roads	Non Built Up	3%	0.4%
	Built Up	8%	4.3%
Minor Roads	Non Built Up	3%	0.4%
	Built Up	8%	4.3%
OVERALL		**5.5%**	**2.5%**

2.2 Travel time

The expected changes in travel time, taken from the micro-simulation modelling, show an increase ranging from 0 to 4.3%. These results are shown in Table 4.

2.3 System costs

The favoured EVSC system is an essentially autonomous system in which:

- An in-vehicle storage device, such as a CD-ROM, contains a digital map of the road network with the speed limits identified.
- A vehicle navigation system with dGPS together with an inertial gyroscope and dead reckoning capability to position the vehicle on the digital map.
- The permitted speed limit is read from the in-vehicle map.
- The ECU receives details of the current speed limit while managing the demands of other vehicle systems and controls the vehicle speed through a combination of engine management and active braking/ traction control.

The major costs of this configuration of EVSC are associated with:

1. Information Supply (map generation, map update and broadcast of information)
2. System Control in the vehicle
3. Human Machine Interface.

For each speed limit system, it is possible to establish the systems costs in terms of an initial establishment cost to set up the system and an annual cost. Table 5 presents these costs both for an implementation now and for the future year 2010. Linear interpolation is used to establish the costs in any intermediate year. The estimated costs for 2010 are used for all subsequent years. Although this approach represents the reduction of manufacturing costs with respect to time and mass production, costs have not been reduced to reflect the possibility of shared use by other telematics applications.

Table 5: EVSC system costs (1998£)

Year	Cost per Vehicle 1998£	Establishment Cost 1998£m			Annual Cost 1998£m		
		Fixed	Variable	Dynamic	Fixed	Variable	Dynamic
2000	2361	8.0	12.0	46.0	2.25 +£5/veh	2.25 +£5/veh	4.84 +£5/veh
2010	372	8.0	12.0	43.0	2.25 +£1/veh	2.25 +£1/veh	4.534 +£1/veh

3. COST-BENEFIT ANALYSIS

For the economic evaluation of EVSC, the net present values (NPV) of costs and benefits are calculated to provide a measure of the economic viability of the concept. For each future year of EVSC the benefits and costs are predicted taking into account the expected increase in the volume of travel, and the increases in GDP which increase the value of time spent travelling or lost through accidents (DoT, 1996). It has been assumed that the accident rate remains constant at the 1998 level. The annual values for the costs and benefits are then discounted to base year sums, and the ratio of benefits to costs is calculated. Costs of EVSC are infrastructure costs, maintenance costs. in-vehicle costs and updating costs. Benefits included are accident reductions and fuel savings. The increase in travel time, which is potentially a negative benefit, has not been counted in the cost-benefit analysis, on the grounds that time saved through speeding is an illegal benefit and therefore not appropriate to count. The exclusion of time saved through speeding is in line with DETR policy on the assessment of safety schemes.

3.1 Assumptions

The economic evaluation has been undertaken using the standard UK cost-benefit approach. A set of assumptions has been made about the timings of the events required to implement EVSC:

- The base year for the analysis is taken as 2005, the year in which it is assumed a decision to implement EVSC is made.
- The analysis period is 30 years from that date.
- The phased implementation would begin in 2013 with new vehicles being fitted with EVSC.
- The benefits have been calculated in proportion to the EVSC penetration[2] from 2013 through until 2019 when it is expected that fleet penetration will be sufficient (60% or more) that the full benefits of EVSC will be realised.
- The digital maps and associated administrative structure would be developed over the three years 2010 to 2013.
- Maintenance costs would accrue from 2013.

3.2 Costs

The discounted costs for both the Advisory and Mandatory EVSC configurations are given in Table 6 and Table 7 respectively. The cost of a Driver Select system is the same as for a Mandatory system since the vehicle functionality is the same in both cases.

There are important points to be noted from these tables. Firstly, due to the time frame the discounting factor and estimated future cost reductions reduce the costs significantly. Secondly and most importantly is that, the bulk of the costs are associated with the vehicle. The in-vehicle equipment accounts for roughly 97% of the discounted costs while the annual updating of the digital maps accounts for a further 2%. Finally the additional cost of providing Dynamic speed limit information over Fixed speed limit information is only 1%.

---

[2] A six-year period for phasing in has been assumed on the basis that 10% of the fleet is renewed each year.

Table 6: Discounted costs of an Advisory EVSC system 1998£m

Cost Item	**Fixed**	**Variable**	**Dynamic**
Infrastructure (Digital Maps and sensors)	4.87	7.30	26.17
Maintenance (Digital Maps and sensors)	13.62	13.62	27.44
In-vehicle Equipment (New Vehicles)	3694.15	3694.15	3694.15
Cost of Annual Map Updates	116.71	116.71	116.71
Total	**3829.34**	**3831.78**	**3864.46**

Table 7: Discounted costs of a Mandatory EVSC system 1998£m

Cost Item	**Fixed**	**Variable**	**Dynamic**
Infrastructure (Digital Maps and sensors)	4.87	7.30	26.17
Maintenance (Digital Maps and sensors)	13.62	13.62	27.44
In-vehicle Equipment (New Vehicles)	5231.02	5231.02	5231.02
Cost of Annual Map Updates	116.71	116.71	116.71
Total	**5366.22**	**5368.65**	**5401.34**

3.3 Benefits

The accident reduction benefits have been developed for the each speed limit variant for both the Advisory and Mandatory control systems using the best estimates of accident reduction. The values for the Driver Select system are taken as 50% of those assumed for the Mandatory system (see Part 3, Section 5). The fuel savings and negative travel time benefits for the Advisory and Driver Select systems are assumed to be 40% and 50% of the Mandatory system respectively. In Table 8 each case has been considered using the forecast growth in travel together with both the High and Low forecasts for the rise in GDP.[3]

---

[3] The procedures for CBA assume that accident costs are proportional to national income, so that they rise in line with GDP growth. Similarly it is assumed that, with higher GDP growth, fuel prices rise more rapidly.

Table 8: Discounted benefits of EVSC 1998£m

System	Fuel Saving	Accidents		
		Fixed	Variable	Dynamic
Low GDP				
Advisory	1460	17816	18772	25534
Driver Select	1826	17987	19626	31046
Mandatory	3651	35973	39252	62092
High GDP				
Advisory	1625	24673	25997	35361
Driver Select	2032	24909	27179	42994
Mandatory	4064	49818	54358	85989

From Table 8 it is clear that the accident savings are the major components of the benefits stream being an order of magnitude larger than the fuel savings. It is also clear that the assumptions made about the growth in GDP have a substantial effect on the size of the accident savings.

3.4 Benefit-cost ratios

Combining the costs of Table 6 and Table 7 with the benefit estimates of Table 8 provides a range of benefit cost ratios in Table 9. Clearly a Dynamic Mandatory system provides the most attractive solution under both GDP growth scenarios.

Table 9: Benefit-cost ratios for basic systems

System	Low GDP Growth			High GDP Growth		
	Fixed	Variable	Dynamic	Fixed	Variable	Dynamic
Advisory	5.0	5.3	7.0	6.9	7.2	9.6
Driver Select	3.7	4.0	6.1	5.0	5.4	8.3
Mandatory	7.4	8.0	12.2	10.0	10.9	16.7

While the Driver Select variants appear to perform poorly, this is because it has the same in-vehicle costs as the Mandatory system. In this respect it may be a “stepping stone” on the path to a Dynamic Mandatory system. The Advisory system costs do not include providing the engine management and retardation capabilities required for vehicle speed control. The two options (Advisory or Mandatory) may be viewed as being mutually exclusive unless the Mandatory functionality is either fitted to vehicles during production or retro fitted. The former is the most technically feasible and considered the least expensive. Re-working the analysis on the basis that all new vehicles are fitted with a Mandatory capability alters the resulting benefit cost ratios for the Advisory system significantly (see Table 10).

Table 10: Benefit-cost ratios (assuming required in-vehicle capability for Mandatory system)

System	Low GDP Growth			High GDP Growth		
	Fixed	Variable	Dynamic	Fixed	Variable	Dynamic
Advisory	3.6	3.8	5.0	4.9	5.1	6.8
Driver Select	3.7	4.0	6.1	5.0	5.4	8.3
Mandatory	7.4	8.0	12.2	10.0	10.9	16.7

All the benefit to cost ratios are in excess of 3.5. Mandatory EVSC has considerably higher benefit-cost ratios than the Advisory or Driver Select systems. The largest ratios are for the Mandatory Dynamic system: 12.2 for the low GDP growth scenario, and 16.7 for the high GDP growth scenario.

4. PROPOSED STRATEGY FOR IMPLEMENTATION

4.1 A path to full implementation

It is clear from the benefits and cost analysis that the benefits of the system are considerable, particularly in safety terms, that the benefits considerably outweigh the costs, and that the benefits of any version of EVSC will be maximised with 100% fitment (even if some benefits tail off above 60% fitment). Indeed, if fitment is voluntary, the safety benefits are not proportional to the percent of vehicles fitted. Rather, there will be differential fitment, as was the case when the fitting and usage of seatbelts were voluntary, in which safer drivers tend to take up the system but more unsafe drivers reject it.

The main dimensions in EVSC deployment are *how intervening* the system should be in operation and *how current* the speed limits themselves should be. The predicted accident savings from EVSC have been discussed in Section 1 of this Part of this report. The predicted impact of EVSC along these two dimensions is shown in Table 11.

Table 11: Predicted injury accident reduction in percent by dimension of EVSC system

How Intervening	Currency of Speed Limits		
	Fixed	Variable	Dynamic
Advisory	10.0	10.0	13.0
Driver Select	10.0	11.0	18.0
Mandatory	20.0	22.0	36.0

It can be seen from Table 11 that the scale of the effect of EVSC on safety is larger along the *Intervention* dimension than along the *Currency* dimension, although the difference is not huge. Public concern about EVSC will also be mainly about the Intervention aspects. In addition, cost of implementing EVSC are more affected by the *Currency* dimension than by the *Intervention* dimension. The greatest benefit gains are therefore along the Intervention dimension. All this suggests that the first-order decision in arriving at an implementation strategy should about the *Intervention* aspects.

A strategy is therefore proposed in which the end goal is mandatory usage in the UK of EVSC on vehicles that are fitted. A number of prerequisites are required to reach this goal, and it is possible to associate time frames with each of these prerequisites.

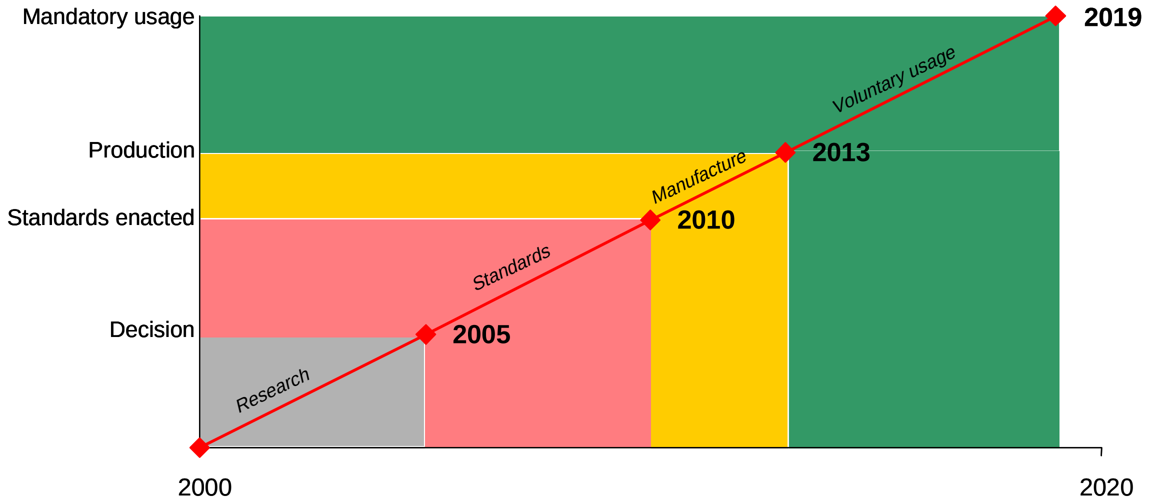

Figure 10: A path to full implementation

Figure 10 shows the major prerequisites and stages to implementing mandatory EVSC. The stages and decision points are:

2000 – 2005	Further research, including larger-scale trials
2005	Decision to move forward towards full implementation
2005 – 2010	Preparation and enactment of standards
2010	Promulgation of standards
2010 – 2013	Preparations for production on new vehicles
2013	Mandatory fitment on new vehicles
2013 – 2019	Voluntary usage
2019	Requirement for mandatory usage

Each of the major stages is discussed in more detail below.

Research stage

Further research is required both on driver behaviour in long-term use of EVSC and on technological aspects, including communications, reliability, digital maps and vehicle control. Work at both a national and European level is needed. The European aspect is particularly crucial for the EVSC technology, since any future standards are likely to be enacted at a European level. It is also important for the *political* process, since both the Commission and the European Parliament will have a role in any decision to require mandatory fitment on new vehicles.

Standards

It is estimated that five years will be required to reach agreement on the standards for:

- Geographic location

- Digital road maps
- Communications for a dynamic system (if desired)
- Interface with the vehicle control
- Vehicle control parameters
- Interface and display aspects

A certification procedure for new vehicles will also have to be agreed.

Translation into mass production

Manufactures will require time to translate the standards into designs for new vehicles and for tooling up for mass production on new vehicles. This is estimated to require three years.

Voluntary usage

Following mandatory fitment on new vehicles, it will not be sensible to move to immediate mandatory usage. Being the sole vehicle using EVSC in a stream of vehicles without EVSC could expose the driver to discomfort and even risk — in particular risk of being struck from the rear. In addition, drivers would be unaccustomed to the behaviour of vehicles with EVSC operating and might be disturbed by system activation.

It would be better to win public confidence in the system through a period of voluntary use when vehicles would have the Driver Select version of EVSC, enabling drivers to switch the speed control on and off at will. This period would be analogous to the period of mandatory fitment but voluntary usage of seatbelts in the front seats of cars prior to the legislation requiring the wearing of seatbelts by front occupants.

The simulation modelling work showed that the major part of the network effects of EVSC are achieved by the time that penetration reaches 60%. Additional system penetration beyond 60% produces only small additional network impacts. The implication is that, once 60% of vehicles are speed-limited, the other vehicles in the network are generally constrained by the speed-limited vehicles and are virtually unable to speed. It would therefore be possible to require usage once 60% of the vehicles in the national fleet are fitted. At this time, the negative aspects of mandatory usage when fitted vehicles are in a minority would no longer be relevant. Since the new vehicles sold in the UK each year constitute approximately 10% of the total vehicle fleet, it would take six years to achieve 60% penetration of equipped vehicles following mandatory fitment on new vehicles.

Mandatory usage

If each of these stages are sequential, then the first possible date for a legal requirement for mandatory usage of EVSC is 2019. This date could be brought forward somewhat if:

- the decision to move ahead were made prior to 2005; or
- if some of the research and standards work took place in parallel.

But it should be recognised that there is not huge scope for compressing the time line to full implementation.

4.2 Benefits and costs of proposed strategy

The benefit and cost analysis outlined in section 3 is here revised to take into account the proposed timing of the transition to EVSC. The assumptions are that:

- All new vehicles from 2013 will be able to operate under a Mandatory EVSC system
- That during the phasing in period (2013 to 2019) a Driver Select system would operate until sufficient fleet penetration (60%) had been achieved.

- In 2019 the Mandatory capability would be “switched on”.

For the period from 2013 to 2019 the assumption has been made that, at any one time, the system is in use by half of the equipped drivers, irrespective of where they lie in the speed distribution, and that the other half do not modify their behaviour in any way. Table 12 presents the resulting cost-benefit ratios.

Table 12: Resulting benefit-cost ratios for proposed EVSC implementation

Traffic Growth	GDP Growth	Fixed	Variable	Dynamic
Nil Growth	Low	4.8	5.2	7.9
	High	6.5	7.1	10.8
Forecast	Low	6.7	7.3	11.1
	High	9.2	10.0	15.4

The proposed EVSC implementation, with a Driver Select system operating during the phasing-in period and with subsequent conversion to a Mandatory system, is very attractive in economic terms under a range of growth assumptions. The benefit to cost ratios are in the range from 4.8 to 15.4.

4.3 Target system

So far, the discussion of implementation strategy has neglected the *Currency* dimension discussed on page 27. Table 11 shows that the accident savings from the Fixed Mandatory EVSC can be almost doubled if the Variable and Dynamic facilities are incorporated. The full Dynamic Mandatory system is slightly more costly overall than the Fixed Mandatory (0.65% more costly). In terms of public (government) cost, the dynamic variant is significantly more expensive, costing 2.9 times as much as the fixed variant. But the increased benefits would seem to justify such additional expenditure. The long time frames to implementation provide the opportunity to carry out further research on sensors to detect problems, algorithms for altering maximum speed and broadcast technologies for transmitting those speeds into vehicles. New broadcast technologies such as UMTS (Universal Mobile Telecommunications System) and DAB (Digital Audio Broadcast) are likely to provide the bandwidth and coverage required for reliable transmission of dynamic speed messages. There is every likelihood that, by 2019, much of the supporting infrastructure could be in place. It therefore would seem sensible that, if the decision is made to move towards Mandatory EVSC, the goal should be to have the Dynamic capability in operation by 2019.

4.4 Institutional, legal and standards requirements

Institutional aspects

Any “approved” national digital road map incorporating speed limits will require new institutional arrangements for its setting up and maintenance. Not only does the initial data collection have to take place with a very high degree of reliability, it will also be necessary to set in place arrangements for producing regular updates for changed limits and downloading them into vehicles. The variable and dynamic variants will require even greater attention to detail and additional institutional arrangements — particularly for the dynamic version where the decision to change a speed limit will have to take place somewhere, albeit perhaps within an automated system equipped with appropriate sensors.

European aspects

From a purely *legal* point of view, it may be possible for the UK to move forward with EVSC implementation on a purely national basis. But such an approach to implementation would have a number of drawbacks:

- It would impose extra manufacturing costs for vehicles sold into the UK market and would therefore be resisted by vehicle manufacturers;
- Unit costs would be higher because of smaller production runs;
- The full integration of EVSC into vehicle design might not be achieved, making tampering and removal easier;
- Cross-border traffic into the UK would not be equipped;
- UK vehicles might not be supported when being driven elsewhere in Europe;
- Different systems with different standards might be implemented in various European countries, leading to reduced interoperability across Europe.

There is a clear case, therefore, for the overall specification and standards for EVSC to be written at a European level and where appropriate at an ECE level. This does not imply that *usage* needs to be mandated at a European level. There are clear issues of subsidiary here, which would have to be resolved at a political level if the EU decided to move ahead with mandatory usage. More acceptable to the various Member States would be a regime that required mandatory *fitment* on all new vehicles sold in the EU after a certain date, with each country able to make its own decisions about whether the system should be enabled and, if so, whether and when it should be enabled in advisory, voluntary (Driver Select) or mandatory configuration.

On this basis, it is sensible to proceed at a European level, with the various standards required to enable EVSC. Such standards need not at this stage presuppose that the end target is mandatory usage, but equally they should not prevent that option from being achievable. The standards work needs to take into account the communications aspects of EVSC, as well as the equipment needed on board the vehicle. New mobile communications systems may allow a configuration in which there is no physical on-board map. This would mean that, on the vehicle, there would be little practical difference between Dynamic and Fixed EVSC, thus making it more attractive to move directly to the Dynamic system.

Legal issues

New arrangements may need to be put in place for Type Approval, and new legislation will be required to enable variable and dynamic speed limits, to outlaw tampering and to create secure evidence of information passed to the vehicle and of vehicle mode for police investigations and court cases. There are also issues of functional system safety, i.e. of the reliability and failure modes of a complex safety-related system. Above all, the introduction of EVSC in a version where usage was mandatory would almost certainly require primary legislation.

CONCLUSIONS AND RECOMMENDATIONS

The major conclusions and recommendations from the project are as follows:

1. EVSC has very large accident-reduction potential and the user trials provide clear indications of safer driver performance with EVSC that would lead to improved road safety.
2. Mandatory EVSC is far more effective than advisory or voluntary EVSC.
3. The Dynamic variant provides the largest accident reduction.
4. Benefit-cost ratios for all variants of Mandatory EVSC are greater than 7.
5. The Mandatory Dynamic system costs little more overall than the Mandatory Fixed system, even though the public costs are substantially higher. It therefore has much higher benefit-cost ratios.
6. The autonomous (non-infrastructure based) architecture for EVSC has significant advantages over the beacon-type system in terms of reliability, flexibility, rapid deployment and reduced public costs.
7. Based on a 2005 decision date and given some reasonable assumptions, new vehicles could be equipped with EVSC on a compulsory basis by 2013, and this could even be brought forward with some earlier standards work.
8. 2019 is a reasonable target date for implementing mandatory usage. If fitment is compulsory from 2013, then by 2019 60% of vehicles would be equipped and the modelling results suggest that at this threshold non-equipped vehicles would be substantially constrained by vehicles using EVSC.
9. If the decision is made to move towards mandatory usage, then the goal should be to have the dynamic system in operation by the same 2019 date.
10. The Driver Select system provides a sensible transition to mandatory usage.
11. Cost-benefit ratios for the recommended implementation path, moving towards having the Mandatory Dynamic system in operation from 2019, are better than 7.
12. EVSC has major prerequisites in terms of standards and institutional arrangements. Changes to the law will be required.
13. A Europe-wide system has considerable advantages over a purely national system.

PUBLIC DELIVERABLES OF THE PROJECT

Deliverable 1: Heather C. Pyne, Review of the Literature on the Relationship between Speed and Accidents. Version 1.0, June 1997.

Deliverable 2: Samantha Comte and Terry Lansdown, Review of Research on External Vehicle Speed Control. Version 1.0, June 1997.

Deliverable 4: Mark Gilmour, Derek Charters, Mark Fowkes, Terry Lansdown, David Ward and Peter Jesty, Technical Approaches to the Implementation of External Vehicle Speed Control. Version 1.0, October 1997.

Deliverable 5: Samantha Comte, Mark Wardman and Gerard Whelan, Acceptability of External Vehicle Speed Control. Version 1.0, October 1997.

Deliverable 6: Fergus Tate, Implementation Scenarios. Version 1.0, October 1997.

Deliverable 7.2: Mark Fowkes, Peter Jesty and David Ward, Legal Implications of External Vehicle Speed Control. Version 2.0, July 2000.

Deliverable 9: Samantha Comte, Simulator Study. Version 2.0, October 1999.

Deliverable 10.: Samantha Comte, On Road Study. Version 3.1, December 1999.

Deliverable 11.3: Ronghui. Liu, James Tate and Rachel Boddy, Simulation Modelling on the Network Effects of EVSC. Version 3.1, October 1999.

Deliverable 12: Ian McKenzie and Mark Fowkes, Review of the Predicted Effects of External Vehicle Speed Control: Implications for the Future UK Vehicle Fleet. Version 1.0, July 1999.

Deliverable 13/14: Mark. Fowkes and Oliver Carsten, Preferred Approach to Implementation and Performance Specification. Version 1.0, June 1999.

Deliverable 15: Andrew Parkes, System/User Interface. Version 1.0, November 1998.

Deliverable 16.2: Mark Fowkes, Production Issues. Version 1.0, July 2000.

Deliverable 17: Oliver Carsten and Fergus Tate, Final Report – Integration. Version 1.4, July 2000.