External Vehicle Speed Control

Phase II Results

Executive Summary

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INTRODUCTION

The External Vehicle Speed Control (EVSC) 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. 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 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.

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

- Cost-effective
- Acceptable
- Logistically feasible
- Safe

This Executive Summary summarises the results of the Phase II of the project. This phase of work began in January 1998 and ended in May 1999. It was the main research phase of the project, following on from the introductory and preparatory work in Phase I (February to October 1997). Phase II covered work in the following areas:

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
8. Legal implications
9. Links with other projects, both within and outside the UK

Of these work areas, (8) and (9) are to produce formal deliverables only at the end of Phase III, i.e. early in 2000. This document presents summaries of the major findings of Phase II. A list of the deliverables produced by the research team is included at the end of the document. These deliverables are available from the Institute for Transport Studies.

The main objectives of Phase II were:

1. to study driver behaviour in controlled conditions;
2. to study driver behaviour in more natural, but less controlled conditions;
3. to estimate the impact of EVSC on network performance, fuel consumption and emissions;
4. to extend to work carried out in Phase I on implementation aspects.

The study of driver behaviour in controlled conditions was carried out on a high-quality driving simulator, which allows the creation of carefully planned scenarios and assures that all the drivers are subjected to the same road conditions and traffic situations. The pre-planned scenarios can include deliberately risky situations.

The study of driver behaviour in more natural conditions was carried out using a specially modified car. The car was equipped with an autonomous EVSC system that used Differential GPS (dGPS) and an on-board digital road map.

For the investigation of traffic, emissions and fuel consumption effects, a micro-simulation model was employed. Three road networks were simulated: an urban network in both peak and off-peak conditions; a rural two-lane highway, and a motorway.

The document groups the work that has been accomplished in a logical sequence. Part 1 covers the practical trials, including the design of the test vehicle, the laboratory (driving simulator) trials and the on-road trials. Part 2 covers the simulation modelling on network impacts. Part 3 summarises the integration work, i.e. the implications of EVSC for the future UK fleet, the investigation of the performance specification for EVSC, and the review of the implementation path.

PART ONE: 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 both on a driving simulator and with 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 as 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. TEST VEHICLE AND HMI

For the simulator and on-road trials, two major versions of EVSC were used. The first was a voluntary system, termed ***"Driver Select"***. Here drivers have the option of whether or not to be limited to the advised speed limit. At each speed limit change on the experimental route, the driver is alerted by a visual display (pictured in Figure 1 as it was implemented on the equipped car) and an auditory prompt. The visual display relays the external speed limit to the driver. At this stage the driver has three choices:

- Firstly, if the driver wishes to engage the system, and thereby be limited to the maximum speed as shown on the display, he/she presses the green button on the steering wheel.
- Secondly, if the driver chooses to override the system, and thus be free to travel at any speed, he/she can press the red button on the steering wheel. Use of the red button disengages the speed limiter and places the system in standby mode (information on the speed limit still appears on the screen).
- Thirdly, the driver can choose to ignore the auditory prompt. If the driver ignores the prompt, he/she is alerted by a second auditory signal. If the driver continues to ignore this, after 4 seconds the system reverts to standby mode, whereby no control is exerted.

The Driver Select system can 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 1: In-vehicle interface

With the alternative ***Mandatory*** system, the maximum speed of the car is permanently limited to the posted speed limit of the road. Thus the driver is never able to exceed the speed limit. The system operates is such a way as to slow the vehicle down when necessary in advance of a speed sign so that they are 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 has 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. Thirty drove the car once without an EVSC system and the following 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 four times with the system off, to provide a baseline. There were thus 160 drives in all.

Speed measurements were taken every 10 metres along the road network. The results suggest that the EVSC systems had little impact on mean speeds, but, as expected, reduced maximum speeds. The effects of the EVSC systems were most prominent at specific locations, such as village entry, where drivers find it difficult to adapt their speed to the lower speed limit. Figure 2 shows the speed profiles across systems for one village entry.

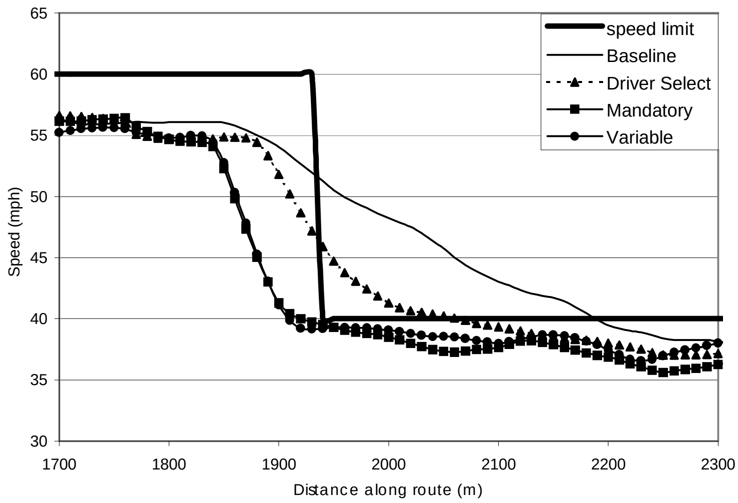

Figure 2: Speed profiles for entry into a village

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 3 shows the results for a left turn with traffic approaching from the right.

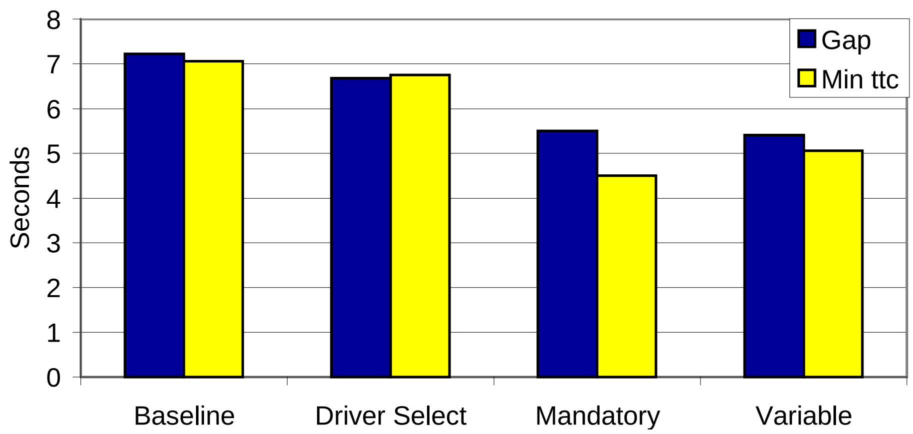

Figure 3: Mean gap accepted and minimum time to collision on left turn merge

Drivers using either the Mandatory or Variable systems may have become increasingly frustrated on increased exposure to the system. 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 4 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).

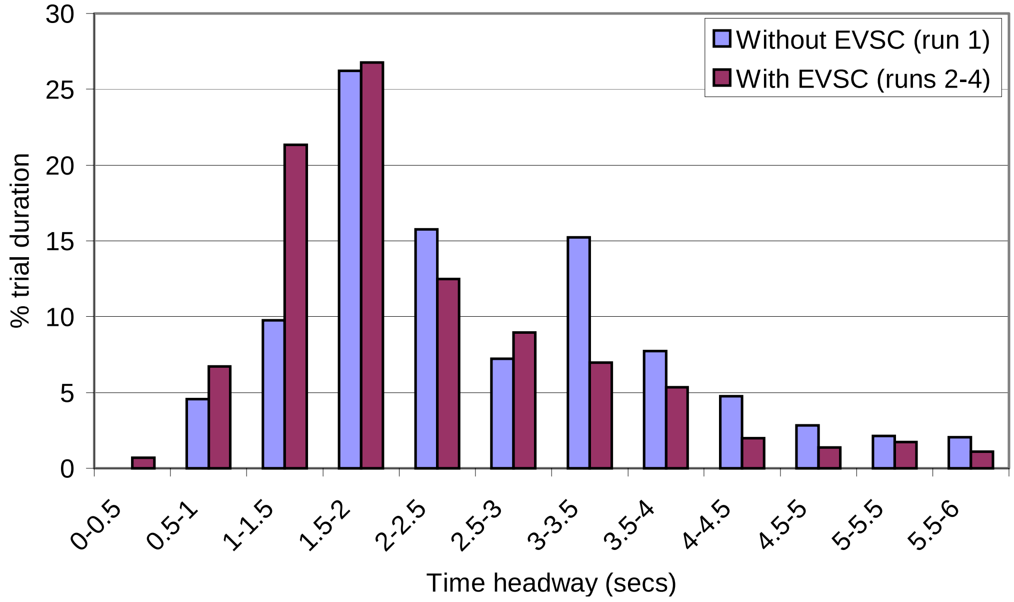

Figure 4: Time headway on urban roads for drivers with Mandatory system

Subjective mental workload scores were obtained and, as in previous studies, both time pressure and frustration increased as drivers used the system more and more. This perceived 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 drivers preferred the Driver Select system. Generally, drivers valued all EVSC systems more highly after having experienced one, with the Driver Select system demonstrating the most improvement in acceptability ratings.

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 also highlighted the fact that any prediction about safety benefits should perhaps be modified in the light 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 car equipped with an External Vehicle Speed Control (EVSC) system. A Ford Escort (pictured in Figure 5) was equipped with two versions of EVSC, Driver Select and Mandatory. Using differential GPS, the position of the car could be monitored with an accuracy of about 1m and with a normal update rate of once per second (a dropout of the GPS or the differential signal could result in slowing the update to 3 seconds). The position and value of every speed limit along the test route was stored in a laptop computer as a "virtual beacon". The EVSC software compared the appropriate 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 for up to 30 seconds. 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 automatic deceleration was in the region of 0.2g.

Figure 5: 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. Data were collected at 10Hz and stored on the PC in the boot of the car. Variables 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; 16 drove the car once without an EVSC system and the following two times with one version of the system (eight with the Driver Select version and eight with the Mandatory one). The other eight participants drove three 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.

Figure 6 shows the use of the system and speeding behaviour for an uncongested urban stretch. For each subject, the left bar shows behaviour on the first drive with the system (Run 2) and the second bar show behaviour on the second drive with the system (Run 3). Figure 7 shows the same data for a rural village. It can be seen 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.

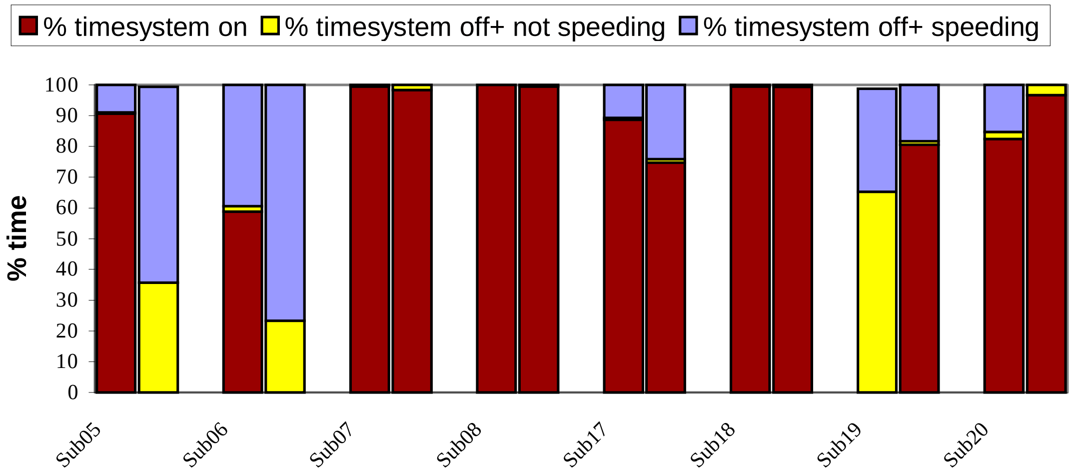

Figure 6: Use of Driver Select system and associated speed choice on a 40 mph uncongested urban road

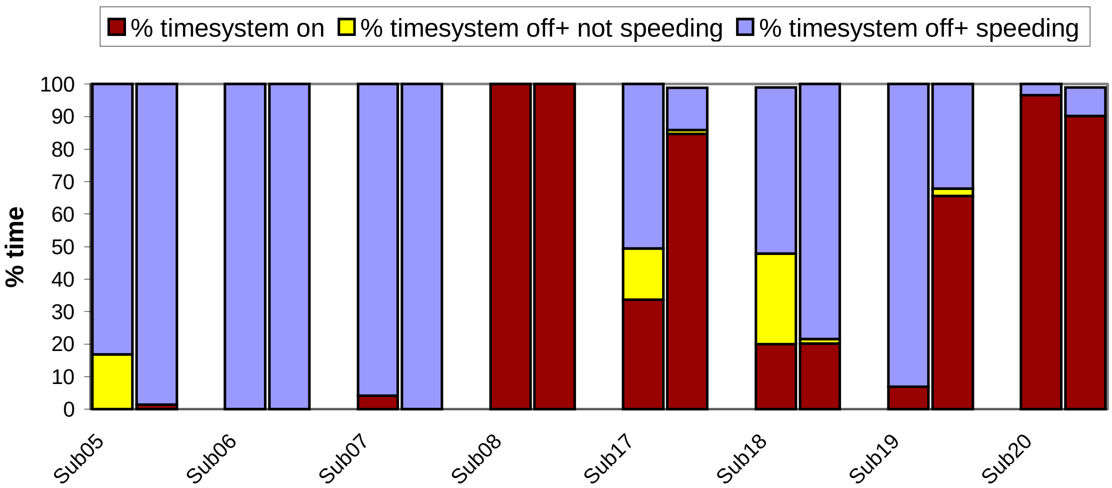

Figure 7: Use of Driver Select system and associated speed choice in 30 mph village

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 8.

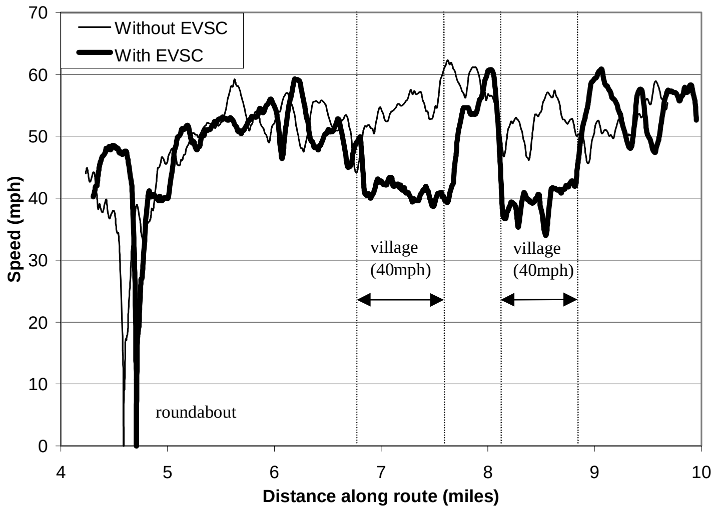

Figure 8: Individual speed profile with Mandatory system

In the absence of the EVSC system, the data shows quite clearly that drivers are poor at adapting to low speeds after travelling through a higher speed limit area. 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 9, 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.

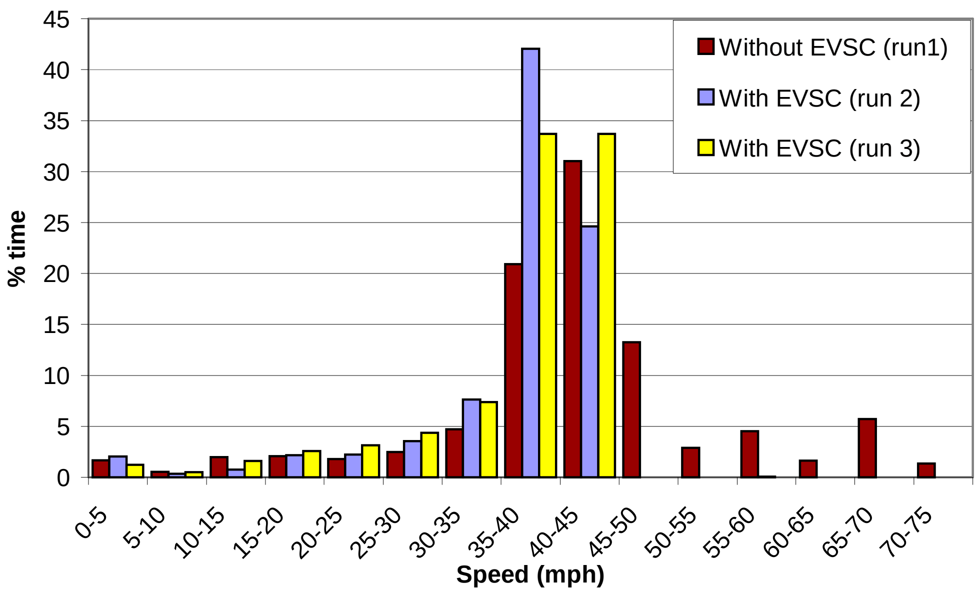

Figure 9: Speed distribution across the 3 trials in urban section (speed limit 40 mph, Mandatory system)

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 10, which shows the conflicts scored by the observers for each run. With EVSC, performance improved; without EVSC, 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.

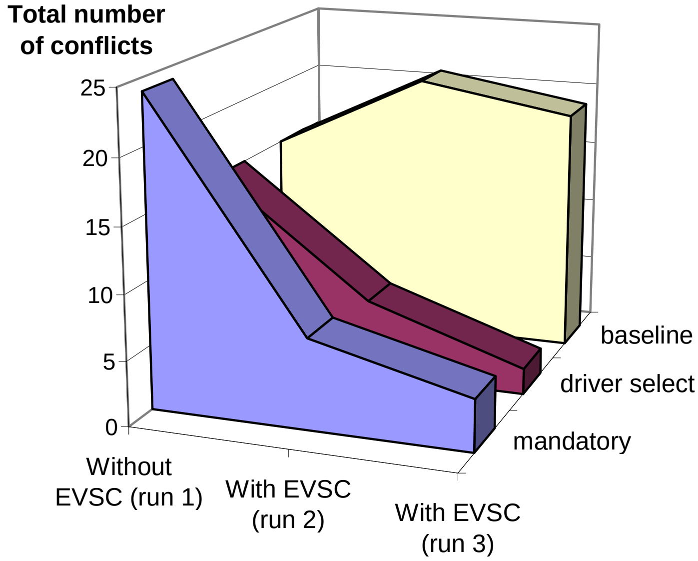

Figure 10: Total number of critical events or conflicts

Subjective rating scales, which described subsets of driver behaviour, were completed for each subject by two observers. 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.

From both the questionnaires and the mental workload evaluation, it seems that 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 areas. However, even after use of the system, driver still thought the systems would create difficulties when overtaking and prevent acceleration out of danger. These comments are probably as a result of the fact that the volunteer drivers were driving in traffic that was not speed controlled. Drivers commented 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.

PART TWO: SIMULATION MODELLING ON THE NETWORK EFFECTS OF EVSC

Simulation modelling provides a cost-effective method and a controlled environment for evaluating EVSC in a network context, and particularly for studying the interactions between equipped and non-equipped vehicles during the transition periods to full implementation. A detailed traffic microsimulation model, DRACULA (Liu et al, 1995 and 1999), was suitably adapted for this work. 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 were also introduced to the model to investigate the interactions between equipped and non-equipped vehicles. Ten levels of EVSC penetration were simulated for each of the four networks and were compared with the base scenario without EVSC. The penetration levels simulated range from 10%, 20%,… to 100%. 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 randomly around 770 vehicle hours. 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. In the off-peak urban scenario, it was seen that without EVSC vehicles exceeded the speed limit for approximately 34% of the time. This amount of high-speed vehicle-hours was simply restricted to the speed limit (30 mph or 40 mph) by full EVSC control. In the peak period, only 20% of such vehicle-hours were restricted. 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 constant speeds. The fuel consumption rate (litre/hour) has a strong and positive relationship with vehicle acceleration, deceleration and cruising speed, i.e. vehicles consume more fuel when in hard acceleration and deceleration, and when moving at higher speeds. In the rural and the motorway situations, fuel consumption was reduced by only 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.

PART THREE: IMPLEMENTATION ASPECTS

1. PREDICTED EFFECTS OF EVSC FOR THE FUTURE UK FLEET

Characteristics of UK vehicle fleet

Analysis of current fleet characteristics and future predictions suggest that the passenger car and derivative category will continue to dominate. The main change in the characteristics of these vehicles in a decade will be the start of diversification in vehicle powertrain as new technologies mature and emissions performance and fuel taxation motivates change. Increasing amounts of electronic control mechanisms for all aspects of vehicle power, transmission, braking and dynamics will consistently be applied. This will be conceivably as an integrated system. Additional electronics to deliver information is also a mass-market reality within a decade, route guidance and traffic information broadcast is being brought to the market in 1999/2000 and will become a standardised item of 2010 vehicles. Other more advanced driver assistance systems will also be applied in this timescale.

It is therefore likely that the fundamental control elements for EVSC functionality will be in place. However the need to direct these market advances towards EVSC as assessed in this project is not yet in place and consideration of the strategic actions required is now timely. The other vehicle types (motorcycles, goods vehicles and buses in the main) will all also reflect similar increases in electronic control application within a decade. The specialised nature of the commercial vehicle sector in particular may suggest that EVSC functionality, and potentially retrospective fit of EVSC may be considered. Motorcycles however present the largest challenge for a future EVSC enabled road environment. The acknowledged difficulty of transferring the passenger car concept and function of EVSC to motorcycles suggests that an alternative and complimentary speed control strategy should perhaps be considered.

Cost of implementation of EVSC

The implications of the roll-out of technology such as GPS and digital data maps into the mass passenger car market may also have profound cost implications into the actual cost of the technology in 2010. The costs estimates available now can be considered as pessimistic estimates based on current polls of opinions. It is equally likely that all of the necessary component parts of a mandatory EVSC will be available on the average new 2010 passenger car, provided for other purposes than EVSC. The additional cost of the EVSC function will therefore be considerably less. Therefore the analysis of cost and benefit carried out in Phase I of the project will be revised in Phase III. In addition major costs of EVSC in a GPS/Data map architecture are borne by the vehicle manufacturer in development, and the vehicle purchaser in use. For this reason the alternative beacon-based DSRC concept of a future EVSC roadway seems less and less attractive particularly if this requires considerable public sector investment. For these reasons the autonomous vehicle equipped with a geographical “sense” of location and on-board database of relevant speed limits still seems the favoured option to pursue.

Relative time to implement EVSC

As noted above it remains clear that EVSC implementation on new vehicles seems appropriately targeted on around 2010. This is supported by perceptions of decreasing cost of on-board equipment and increasing penetration of appropriate potentially adaptable and integrated control mechanisms. Introduction may be considered at an earlier date but may have greatly increased technical difficulty and initial cost.

Technical development(s) required to implement EVSC

For most road vehicles, cars and commercial vehicles, the technical developments required for EVSC may well be limited. However the main outstanding issue remains to be how motorcycles can be introduced to the future controlled UK roadway with a level of speed control that ensures a beneficial safety outcome. This is a concern for Phase III of the project.

2. PREFERRED APPROACH TO IMPLEMENTATION AND PERFORMANCE SPECIFICATION

Work here indicated that the automotive industry is actively following a development path that requires a number of underlying technologies to support various envisaged driver assistance applications. These same technologies and sub-systems could be exploited for totally different vehicle functionality than the ones currently envisaged by the manufacturers. Such potential applications include EVSC.

A provisional development path for EVSC with increasing functionality over time was proposed as follows:

T0	External SL display /Driver Control (Current Practice)
T1	In-vehicle SL display /Driver Control (In-vehicle SL display)
T2	In- vehicle SL display /Driver Assistance (Driver Select)
T3	In-vehicle SL display /Automatic Speed Set (Mandatory)
T4	In-vehicle SL display / Automatic Speed Set (Variable)
T5	In-vehicle SL display /Auto Speed Set with broadcast update (Dynamic)

The provision of T1 EVSC needs digital map databases enhanced to provide Speed Limit data and a GPS-type location system. The information on speed limit then needs to be passed to the driver in the form of a definable HMI. The transition from T1 to T2 EVSC requires interfaces from the SL information system to the Powertrain control via some HMI including simple controls. Moving from T2 to T3 deletes the intervening controls and delivers SL data directly to powertrain control. Moving from T3 to T4 requires an enhanced map, which would allow the vehicle to "view" the road ahead and identify features such as pedestrian crossings and sharp curves. It is relevant here to note that the car manufacturers and navigation system providers are intending to collaborate in the development of far more detailed digital road maps. Such road maps would improve the performance of Adaptive Cruise Control and Collision Avoidance Systems, but they could also be employed in EVSC to identify, for example, curve radius before curve entry so that vehicle maximum speed could be adjusted accordingly. Moving from T4 to T5 requires additional dynamic information to be supplied and therefore an additional data source would need to be interfaced to the vehicle. This could be in the form of broadcast messages over some kind of radio network (cellular phone, DAB, etc.). The systems outlined are not the only possible variants of EVSC — other intermediate systems and mixes of system are also feasible — but they are the most significant ones.

The review that has been undertaken of positioning systems based around one or other type of GPS and of developments in navigation technology with predicted enhancements in digital road maps has indicated that the "autonomous" architecture for EVSC is the best way forward. This is in part because it will not require a huge investment in roadside infrastructure, but also because future vehicles are likely to have many of the enabling technologies as standard fitment. However, there are still choices to be made in terms of the features of EVSC, in particular on whether the initial system should include the Dynamic element.

A strategy for implementing EVSC needs to consider both how to maximise the benefit to cost ratio and create a provisional timetable based on the need for standards, the availability of technologies and the predicted permeation of EVSC-equipped vehicles though the fleet. Phase III of the project will deliver a further refinement of these issues and a final set of recommendations.

CONCLUSIONS

The major conclusions from Phase II of the project are:

User trials:

- With EVSC, driving speeds were better adapted to the road situation. This was particularly noticeable with the Mandatory system in the rural villages.
- With EVSC, the drivers in the on-road trials had fewer conflicts when driving with the Mandatory system.
- There was no evidence of drivers being "out of the loop" in either the on-road or the simulator drives.
- Drivers using the Driver Select system in the on-road trials tended to switch it off when they were not restrained by road or traffic conditions. When it was off, they tended to be speeding. Both effects were more marked, the second time the system was used.
- There were some indications of behavioural adaptation in the simulator drives. With EVSC, drivers tended to adopt shorter headways in following a slow lead car and to accept smaller gaps at junctions. These effects could not be confirmed in the on-road trials, because the EVSC car was generally slower than the leading traffic and because the drivers did not have to make many gap acceptance judgements similar to those encountered in the simulator route.
- In the on-road trials there were no indications of a speed adaptation effect in which drivers would attempt to make up for the constraints imposed by EVSC by trying to go faster when at slower speeds.
- With EVSC, successive drives on the real-road route produced a reduction in traffic conflicts. Without EVSC, increased familiarity with the route seemed to result in a greater number of conflicts.

Simulation modelling on network effects:

- EVSC had negligible effect on congestion or journey time for all the networks modelled. Even in the urban off-peak situation, the increase in journey time, while discernible, was small in relative terms.
- There is a substantial predicted savings in fuel consumption with EVSC — 8% on the urban peak and off-peak networks and 3% on the rural two-lane network.
- 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.

Implementation aspects:

- Many of the systems and technologies required to implement an autonomous EVSC (i.e. one not requiring roadside beacons) will be fitted as standard to future vehicles. This will considerably reduce the costs of implementing EVSC.
- A provisional development path for EVSC implementation has been proposed. This path would provide increasing system functionality over time.
- In order for such a development path to become reality, a number of standards would have to be put into place. There is thus a crucial role for standards-making institutions.

PHASE III OF THE PROJECT

Phase III of the project's work is now under way. The major tasks are to examine how EVSC could go into mass production on all vehicle types and to produce a final integration report reviewing the cost and benefits of EVSC in the light of the project's research findings and proposing a strategy for implementing EVSC in the UK. In addition, the project will deliver the end report on the legal implications of EVSC and the end review of relevant activities in other projects being carried out in the UK, in other European countries and at a European level.

PUBLIC DELIVERABLES FROM PHASE II

Deliverable 9:	S. Comte, Simulator Study, October 1999.
Deliverable 10.:	S. Comte, On Road Study, November 1999.
Deliverable 11-3:	R. Liu, J. Tate and R. Boddy, Simulation Modelling on the Network Effects of EVSC, October 1999.
Deliverable 12:	I. McKenzie and M. Fowkes, Review of the Predicted Effects of External Vehicle Speed Control: Implications for the Future UK Vehicle Fleet, July 1999.
Deliverable 13/14:	M. Fowkes and O. Carsten, Preferred Approach to Implementation and Performance Specification, June 1999.
Deliverable 15:	A. Parkes, System/User Interface, November 1998.