External Vehicle Speed Control

Deliverable D17

Final Report: Integration

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Glossary

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
dGPS	Differential Global Positioning System — the accuracy of normal GPS is enhanced with a broadcast correction signal
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)
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
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

1. INTRODUCTION

This report is the final report of the three-year External Vehicle Speed Control project. It does not attempt to summarise all the major findings of the project — that task will be accomplished by a separate executive summary of the project findings. The report concludes Phase III of the project. Other deliverables from this phase are D7.2 – Legal Implications of External Vehicle Speed Control Issues and D16 – Production Issues. The major objective of Phase III has been to prepare an implementation strategy for EVSC, taking into account system costs, predicted benefits, any major disbenefits and timescales for introducing EVSC.

This report draws on all the previous work of the project to review the case for moving forward with EVSC and to propose an implementation strategy by which EVSC could be rolled out if such a rollout can be justified. It presents the conclusions from the project concerning the technologies and system architecture for EVSC, the time required for implementation, and the predicted accident savings. The initial benefit-cost analysis carried out at the end of Phase I of the project in Deliverable 6 – Implementation Scenarios, has been revised in the light of the results from the simulation modelling carried out in Phase II on network effects on EVSC and in the light of the behavioural studies of user behaviour with EVSC. The costs of implementation have also been revised, drawing on more recent information about the future costs of the various sub-systems required.

Chapter 2 of the report reviews some of the implications of the project's research for the implementation of EVSC. Chapter 3 presents the accident savings that are predicted for the major variants of EVSC. In Chapter 4, the network impacts of EVSC as predicted by the simulation modelling conducted by the project are presented. Chapter 5 reviews the economic costs of implementing EVSC and Chapter 6 presents the benefit-cost predictions for the major system variants. A proposed strategy for the implementation of EVSC is presented in Chapter 7 and the conclusions and recommendations of the report are summarised in Chapter 8.

2. IMPLICATIONS OF PROJECT FINDINGS FOR IMPLEMENTATION

2.1 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. From this, a number of inferences followed:

- Geographic roll-out of EVSC would be progressive. Deployment could begin in urban areas and then spread to rural roads and finally to motorways, or it could even begin with accident blackspots and then spread to less dangerous sites and roads.
- The *public* costs of implementation would be large, since DSRC beacons used only for this function would probably be required. The estimate in Deliverable 6 was that approximately 150,000 beacons would be required just to transmit the changes in the fixed (posted) speed limits. Special gantries might be required on multilane roads.
- Deployment would be lengthy, because of the long time frame required for equipping the entire UK road network. As a consequence, there would be a number of years when drivers of EVSC-equipped vehicles received EVSC information only on some parts of the network. This could create ambiguities and confusion. Because EVSC would also take time to permeate through the vehicle fleet, at the beginning only a small minority of drivers would receive roadside EVSC signals and those signals would be broadcast only at a small minority of locations. Effectiveness would thus be greatly reduced, since it would be difficult to make EVSC function as a mandatory system in these circumstances. Therefore a large initial cost would be required for a small initial benefit.
- An EVSC system such as this may *not* be pan-European. Certainly, UK EVSC-equipped vehicles would only receive EVSC support in those countries that had installed a beacon network. The German transport ministry has registered its public opposition to the installation of EVSC beacons, and therefore inter-operability would almost certainly be a problem.
- Purchase of an EVSC vehicle would not bring with it other “free” ITS systems, such as navigation systems. It may be seen as a stand-alone application.
- Reliability could be a problem. Trials with DRSC applied for road tolling and for the transmission of roadside information into the vehicle in the Road Traffic Advisor project have shown that it is hard to achieve near-100% reliability in roadside-to-vehicle or vehicle-to-roadside communications.

Once the project got underway, the project team discussed the feasibility of alternative system architectures to provide the same EVSC functionality as the beacon-based approach. An approach 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. This concept is illustrated in Figure 1.

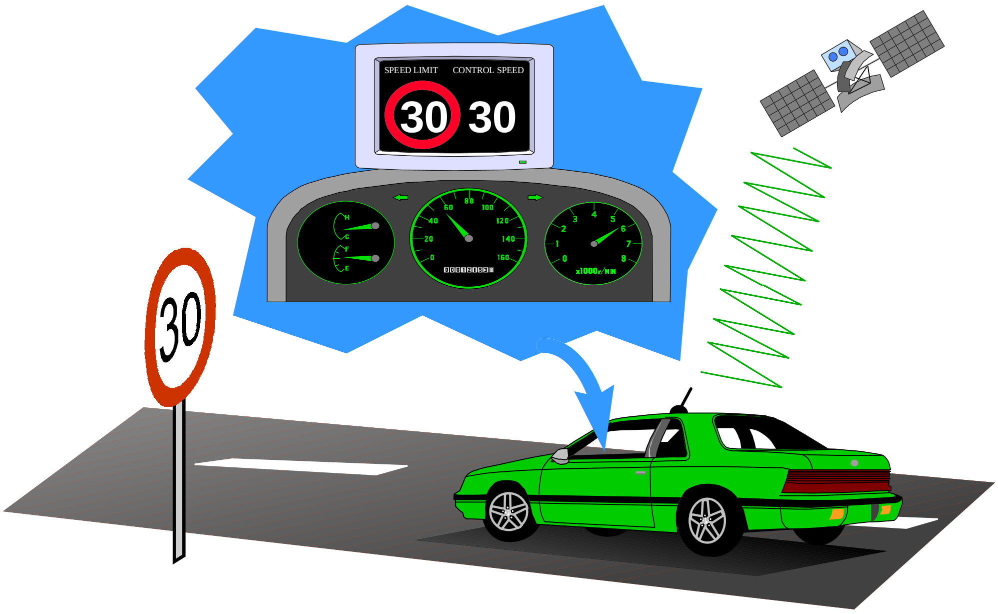

Figure 1: Concept of autonomous EVSC system

Almost as soon as the UK project team had conceived of this alternative architecture, it emerged that a similar path was being pursued in Sweden. As part of the Swedish national project work a practical demonstrator of this concept was also being built by the University of Lund. The Dutch trial of Intelligent Speed Adaptation in Tilburg is also using the autonomous architecture. Perhaps 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 such as the system tested in Berlin in the late 1980s 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 has been implemented in the UK project test vehicle, albeit in simplified form. This vehicle uses:

- a premium (subscription) differential GPS 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 has proved to be a hugely successful demonstrator of this autonomous EVSC concept. To provide the test route, there were no infrastructure maintenance requirements at all (i.e. no physical beacons to service). This has allowed speedy implementation of routes for both experimental investigation and demonstration. In addition the vehicle has performed with a very high degree of reliability and repeatability throughout the three months of the on-road trials, with no observed failures of the navigation part of the system (indeed no detected failures at all). This occurred in spite of initial worries about loss of the differential signal, “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 would be immediate. All equipped vehicles would be provide with EVSC support, wherever they were in the network. There would be no need to prefer one type of road over another.
- 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.
- 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.
- 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. Benefits would then 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.
- The EVSC system would function across Europe, provided appropriate digital road maps were available. Germany has indicated that an autonomous and voluntary EVSC would be acceptable.
- 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. With the beacon-based system, a failure of a vehicle to receive the beacon transmission would mean that, until the next beacon was passed, the vehicle would have incorrect speed limit information. With the autonomous system, there is the possibility of almost immediate recovery from a momentary dropout.

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.

2.2 VARIANTS OF EVSC

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, etc. With a Dynamic system, speed limits are current temporarily.

Here again some variation is possible. Thus speed limits outside schools at times of school entrance and egress could be implemented though a Dynamic system, but they could also be implemented through a Variable system, which had additionally a calendar of school days as part of its on-board database.

A third dimension (one that only applies to Voluntary and Mandatory EVSC) is the strictness with which the EVSC control is applied. To date, the speed-controlled cars built outside the UK have tended to use a haptic throttle, i.e. a throttle pedal that gets more stiff the greater the excursion from the speed limit, and not to apply any braking. This configuration has some shortcomings:

- feedback is only provided when the driver's foot is on the accelerator pedal;
- the driver is able to override the feedback quite substantially;
- deceleration may be very slow so that on entering a slower speed zone the vehicle could be speeding for 0.5 km or even 1.0 km;
- the vehicle will be able to overspeed on downward gradients.

Because of these shortcomings of the haptic throttle, the project has implemented a vehicle using a combination of "dead throttle" and active braking. The initial retardation is achieved not through feedback through the driver's foot but by intervening between accelerator position and engine control (in our case through a combination of ignition retardation and fuel starvation, but more ideally through a throttle-by-wire system). 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.

2.3 BEHAVIOUR WITH MAJOR SYSTEM VARIANTS

When carrying out the initial assessment of implementation aspects in the first phase of the project (Deliverable 6), there were no data available on compliance with or usage of a voluntary EVSC system that interacted with the vehicle controls, in other words the Driver Select system. Such compliance was one of the major issues explored in the on-road trials (Deliverable 10). Subjects who were assigned the Driver Select variant drove twice along the test route with the system. They could engage or disengage the speed limiter at will. In other respects the limiter behaved as in the Mandatory mode. 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 and low levels of satisfaction with the system. There was one road section where, prior to the trials even starting, it was decided not to implement the posted speed limit, because it was felt that it might actually endanger the subjects. This was in a construction zone on a rural dual carriageway where temporary signs with a 30 mph limit had been posted. Other traffic, including heavy goods vehicles, were often going at 50–60 mph through this zone. **This suggests 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.

2.4 NETWORK EFFECTS

Micro simulation modelling of the network effects of EVSC has been carried out using the DRACULA model. The modelling was done with simulations of current vehicles (i.e. current performance, fuel consumption and emissions), current flows and on a current network (for the urban network this meant current signal timings). The aim was to investigate the impact of increasingly higher proportions of the vehicle fleet operating under EVSC. Specifically the micro simulation modelling considered the impact of EVSC on the distribution of vehicles speeds, travel time, fuel consumptions, and vehicle emissions. 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. Three road networks were considered:

- Urban
    - Peak
    - Off Peak
- Rural
- Motorway networks

Table 1 summarises the key results of this work; details of the investigations are reported in Deliverable 11.3.

Table 1: 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 saturation penetration has been estimated at 60%.** Although these findings represent a refinement in the prediction and will be used in considering the national impact of EVSC, it should be noted that they 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.

It should also be noted that EVSC is likely to have the effect of reducing variability in travel time by making traffic flows more smooth. This would make journey times more predictable and therefore may have the effect of reducing the time that drivers allocate in planning their trips (as opposed to the time that they actually spend on those trips).

3. PREDICTED ACCIDENT SAVINGS

3.1 INTRODUCTION

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 (e.g. Perrett and Stevens, 1996) have been based on the findings of in-depth accident studies which purport to show that in a proportion of accidents — the proportion is in the range of 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 and this modification has generally been downward, particularly for urban roads. This makes it unwise to rely on expert assessments of appropriate speeds, made in studies carried out twenty or even ten years ago.
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. This is a matter of Newtonian physics: the energy dissipated in a crash goes up with the square of collision speed. Thus, Andersson and Nilsson (1997) concluded that, for a given type of road, the injury accident rate changes with the square of a change in mean speed, the severe injury (including fatal) accident rate changes with the cube of speed change and the fatal accident rate changes with mean speed to the fourth power.

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.[1] Some of this evidence relates to implementations of speed-reducing measures on single roads or on road networks and the consequent accident savings from such implementations. Even more important, since it is closely related to the effect of EVSC, is information on the relationship

[1] The relevant literature is reviewed in Deliverables 2 and 6.

between the proportion of vehicles speeding (exceeding the speed limit) and accident risk. Cross-sectional analysis carried out in the European MASTER project on data for rural single-carriageway roads shows that the accident frequency was related to the proportion of vehicles exceeding the speed limit (Baruya, 1998a; Baruya 1998b). As regards before and after studies, there is considerable evidence on the impact of measures which have reduced or eliminated the proportion of vehicles exceeding the speed limit and thereby reduced not only mean speeds but also speed variance. Here evidence on the impact of enforcement and traffic calming is highly relevant.

3.2 THE MATHEMATICAL RELATIONSHIP BETWEEN SPEED CHANGE AND CHANGE IN ACCIDENT FREQUENCY

Since the initial work on the expected accident reductions (Deliverable 6) was completed, new research has come to light. A review of this work and, particularly that completed as part of the EU funded MASTER project (Baruya, 1998a; Baruya, 1998b; Baruya et al., 1999) has been undertaken. This research represents a significant advance in our understanding of the speed accident relationship. It identifies that accident frequency on single lane trunk roads (A and B class) in the UK is related not only to mean speed but also to the variation in speed. In turn, speed variation is a function of the proportion of traffic exceeding the speed limit and the proportion of slow vehicles. As a result, the accident frequency on a particular section of road may be directly related to the proportion of drivers exceeding the speed limit on that section of road. It should however be noted that this work is based on a cross-sectional study i.e. it compares different road sections rather than a before and after change.

In the more generalised form (Baruya et al., 1999), this research identifies that the change in accident frequency for each 1km/h reduction in mean speed is inversely related to the current mean speed. However, in order for us to use this relationship to predict accident reductions it is necessary to know at least the mean speed on each road. The alternative is to use an average value for the expected percentage reduction in accidents. A typical value for rural speed limits is a 2% to 2.5% reduction in accidents per 1 km/h reduction in mean speed. In areas governed by urban speed limits and having mean speeds between 30 mph and 40 mph, the road environment plays a big part in determining the likely accident reductions which vary between 1% and 3% per 1 km/h change in mean speed. Without detailed knowledge of the road situation, it is impossible to determine which is the most appropriate value and as a consequence a mean value of 2% could be assumed. While both these values are slightly lower than the estimates previously used in D6, the difference is not sufficient to warrant revising the previously used values linking predicted accident reduction to changes in mean speed and changes in speed variance.

The numbers used for the relationship between changes in mean speed and accident risk were that, for each 1 mph change in mean speed the change in accident risk was as follows (derived from Finch et al., 1994):

Low estimate	3.75%
Best estimate	5.00%
High estimate	9.70%

The above numbers were applied to create the estimates for **Advisory** EVSC. Based on findings from Finch et al. (1994), the change in accidents was capped at 25%. For **Mandatory** EVSC, an additional element was introduced, namely the fact that such a system *transforms* the distribution of speeds by cutting off all speeds in excess of the limit. The formula applied for the relationship between speed variance and risk was as follows:

$y = 0.0139x^2 + 0.0140x$
where y is relative risk
and x is speed difference of a vehicle from mean speed in mph

This formula was derived from West and Dunn (1971). The application of these relationships is discussed in greater detail in Deliverable 6.

3.3 ACCIDENT REDUCTIONS PREDICTED

The accident reduction predictions of Deliverable 6 were based around three levels of speed limit advice and two types of system operation:

- Speed Limit system
    - Fixed speed limits
    - Variable speed limits
    - Dynamic
- System operation
    - Advisory
    - Mandatory

As the Speed Limit systems increase in complexity, it becomes possible to specifically address particular types of accidents as shown in Table 2.

Table 2: Target accident types for different speed limit systems

Accident Type	Speed Limit System		
	Fixed	Variable	Dynamic
General	✓	✓	✓
Adverse Geometry		✓	✓
Darkness			✓
Adverse Weather			✓
Adverse Road Surface			✓

The effectiveness of EVSC in addressing these accident groups is also related to the mode of System Operation and how the system affects the distribution of traffic speeds. In Deliverable 6 we identified that EVSC is expected to modify the distribution of traffic speeds through a combination of two mechanisms:

1. *Translation* in which the shape of the speed distribution remains essentially the same,
2. *Transformation* in which the shape of the speed distribution is dramatically changed.

It is assumed that the provision of speed limit advice (in the Advisory system) will translate the speed distribution downwards. In this case the accident reduction is related to the expected change in mean speeds. Typically changes in mean speed resulting from the provision of speed limit advice, are in the order of 40% of the difference between the original mean and the new advisory speed. The predicted accident reductions for the Advisory system (Table 3) are constructed by combining the expected changes in mean speed with the relationships linking speed and accident frequency that were presented in section 3.2.[2]

The table shows the predicted reductions for various forms of advice: firstly, general advice on the legal speed limit; next advice on road geometry, i.e. sharp horizontal curves, with a variable system; then advice with a dynamic system on slower speeds in darkness; and finally advice with a dynamic system on speeds in bad weather and on slippery roads. The specific criteria used for the advised maximum speeds are discussed in Deliverable 6. The table shows the estimated percent reductions in each set of relevant accidents.

Table 3: Predicted accident reductions for Advisory system

Application	Road Type	Severity	Estimated Accident Reduction (%)		
			Low	"BEST"	High
General Speed Limit Advice	Non Built Up	All Injury	8.7	17.5	25*
	Built Up	All Injury	0	6.5	19.4
Geometry Related	Non Built Up	All Injury	0	10	20
Darkness	Unlit Dual Carriageway#	All Injury	0	20	48.5
Adverse Weather and Road Surface	Non Built Up	All Injury	7.5	20	48.5

*Maximum reduction capped at 25%.
#Assumes mean night-time speed on dual carriageways is 68 mph.

With a Mandatory system vehicles will no longer be able to exceed the speed limit and this will radically change the shape of the speed distribution. The accident reduction is then related to the change in area under a distribution formed from the product of the speed distribution and speed accident relationship. This approach, discussed in section 3.2, has been used to derive the accident reductions for the versions of a Mandatory system as shown in Table 4.

Three versions of a mandatory EVSC are considered: *fixed*, in which speeds are limited to the posted speed limits; *variable*, in which speed limits vary by location with lower speeds for sharp horizontal curves; and *dynamic*, in which speed limits vary by time depending on

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[2] It should be noted that the predictions here and subsequently are for *accident* reduction. Changes in the number of *casualties* will be similar to but not identical to changes in the number of accidents.

the prevailing conditions. The table gives, for each version of the mandatory system, the percentage of accidents within each accident type that would be eliminated. It should be noted that the procedure used in making these estimates was such that double counting is eliminated, i.e. for the variable and dynamic systems only the additional accidents that would be eliminated are shown.

Table 4: Predicted accident reductions for Mandatory systems

System	Road Type	Severity	Accident Type	Estimated Accident Reduction (%)		
				Low	"BEST"	High
Fixed	Non Built Up Roads	All Injury	All	10	31	56
	All Built Up Roads	All Injury	Pedestrian	13.5*	21	28
	All Built Up Roads	All Injury	Non Pedestrian	10#	15	20#
Variable	Non Built Up Roads	All Injury	Geometry-based single carriageway	30	41	74
Dynamic	Non Built Up Roads	All Injury	Darkness	23	37†	50
			Rain and wet road	10	30†	50
			Snow	33	57†	80

*Mean weighted by length of highway designated as 30 mph and 40 mph.
#High and Low estimates assumed at ± ⅓.
†Best estimate taken as middle of range.

As discussed in section 2.3, the overall finding from the user trials was that, compared with the baseline (no EVSC) situation, the speed change for drivers using the Driver Select system[3] was approximately half that of drivers using the Mandatory system. **It has therefore been assumed that the net effect of Driver Select on any factor of interest (accidents, fuel consumption, etc.) is half that of Mandatory EVSC.**

The expected levels of accident reduction for the Advisory and Mandatory systems, Table 3 and Table 4, respectively have been applied to the accident data for 1998 (DETR, 1999b) to give the annual accident savings in Table 5 and Table 6. The accident savings are given for the fixed, variable and dynamic versions of both advisory and mandatory EVSC, and are

[3] The initial version of the "Driver Select" system, as presented in Deliverable 6, allowed drivers the choice of being controlled to one of a series of pre-set speed limits. However, during the Phase II investigations this system has been revised to provide drivers the choice to accept, or reject, the same control as available under the Mandatory system.

broken down by road class. It should be noted that it is assumed that the dynamic version will also have the capabilities of the variable version.

Table 5: Predicted 1998 injury accident savings for Advisory EVSC

System	Road Class	Low Est	Best Est	High Est
Fixed	A Roads (Non Built Up)	3,043	6,122	8,746
	Other Non Built Up Roads	1,863	3,747	5,353
	All Motorways	771	1,551	2,215
	A Roads (Built Up)	–	4,864	14,516
	Other Built Up Roads	–	6,425	19,176
	Total Accident Reduction	**5,677**	**22,708**	**50,005**
	As a % of Total Accidents	**2.4%**	**10%**	**20.9%**
Variable	A Roads (Non Built Up)	3,043	6,666	9,735
	Other Non Built Up Roads	1,863	4,080	5,958
	All Motorways	771	1,551	2,215
	A Roads (Built Up)	–	4,864	14,516
	Other Built Up Roads	–	6,425	19,176
	Total Accident Reduction	**5,677**	**23,585**	**51,600**
	As a % of Total Accidents	**2.4%**	**10%**	**21.6%**
Dynamic	A Roads (Non Built Up)	4,173	10,203	17,105
	Other Non Built Up Roads	2,554	6,245	10,469
	All Motorways	990	2,254	3,724
	A Roads (Built Up)	–	4,864	14,516
	Other Built Up Roads	–	6,425	19,176
	Total Accident Reduction	**7,718**	**29,991**	**64,990**
	As a % of Total Accidents	**3.2%**	**13%**	**27.2%**

Table 6: Predicted 1998 injury accident savings for Mandatory EVSC

System	Road Class and Accident Type		Low Est	BEST	High Est
Fixed	A Roads (Non Built Up)		3,498	10,844	19,590
	Other Non Built Up Roads		2,141	6,637	11,990
	All Motorways		886	2,747	4,962
	A Roads (Built Up)	Non Pedestrian	5,719	8,578	11,438
	Other Built Up Roads		7,555	11,332	15,109
	A Roads (Built Up)	Pedestrian	2,381	3,704	4,938
	Other Built Up Roads		3,145	4,893	6,523
	Total Accident Reduction		**25,325**	**48,735**	**74,551**
	As a % of Total Accidents		**11%**	**20%**	**31%**
Variable	A Roads (Non Built Up)		5,279	12,710	21,737
	Other Non Built Up Roads		3,231	7,779	13,304
	All Motorways		886	2,747	4,962
	A Roads (Built Up)	Non Pedestrian	5,719	8,578	11,438
	Other Built Up Roads		7,555	11,332	15,109
	A Roads (Built Up)	Pedestrian	2,381	3,704	4,938
	Other Built Up Roads		3,145	4,893	6,523
	Total Accident Reduction		**28,195**	**51,742**	**78,012**
	As a % of Total Accidents		**12%**	**22%**	**33%**
Dynamic	A Roads (Non Built Up)		8,786	18,317	26,800
	Other Non Built Up Roads		5,378	11,211	16,403
	All Motorways		1,697	4,049	6,215
	A Roads (Built Up)	Non Pedestrian	10,789	18,528	25,531
	Other Built Up Roads		14,252	24,475	33,726
	A Roads (Built Up)	Pedestrian	2,381	3,704	4,938
	Other Built Up Roads		3,145	4,893	6,523
	Total Accident Reduction		**46,428**	**85,175**	**120,138**
	As a % of Total Accidents		**19%**	**36%**	**50%**

Table 7 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 calculations for the effect of EVSC on fatal and serious accidents and on fatal accidents has been made by applying the formula of Andersson and Nilsson (1997). As discussed in section 3.1, they concluded that, for a given type of road, the injury accident rate changes with the square of the ratio of a change in mean speed, the severe injury (including fatal) accident rate changes with the cube of speed change and the fatal accident rate changes with speed change to the fourth power. The prediction is that the most powerful and versatile form of EVSC, the Mandatory Dynamic system, will reduce fatal and serious accidents by 48% and will reduce fatal accidents by 59%.

Table 7: 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%

4. NETWORK EFFECTS OF EVSC

In addition to investigating the impact of different levels of EVSC penetration the micro simulation modelling (D11.3) also investigated the impact of EVSC on fuel consumption and travel time. The micro simulation modelling identified that EVSC will reduce the fuel consumption and increase travel time. The impacts should therefore be quantified and incorporated into the benefit cost analysis.

4.1 FUEL CONSUMPTION

The annual petroleum consumption for road transport in tonnes is given in DETR (1999b) together with the average price per litre. The conversion from tonnes to litres depends on the fuel type Leaded, Unleaded (super and premium) and Diesel (DERV). For the purpose of this study, an average of super and premium unleaded conversion factors has been used to produce the annual volume of fuel used.

Since Table 1 identifies different levels of saving by speed limit, it is necessary to disaggregate the total fuel saving by road type. The volume of travel (vehicle kilometres) on built up and non built up roads (DETR, 1999b; Table 4.10) has been used in conjunction with fuel consumption test data[4] to apportion fuel usage by road type as shown in Table 8. An underlying assumption is that the savings will be similar, in percentage terms for petrol and diesel vehicles.

Table 8: Determination of fuel consumption by road type

Road Type	Fuel Drive Cycle	Fuel Usage Weighting Factor		Vol. of travel 10^9 veh.km	Fuel Usage 10^6 litres	
		Petrol	Diesel		Petrol	Diesel
Motorway	Extra Urban	1	1	81.8	3884.87	2481.66
Major						
Non Built Up	Extra Urban	1	1	132.6	6351.83	4057.56
Built Up	Urban	1.789	1.636	79.1	6778.63	3959.88
Minor						
Non Built Up	Extra Urban	1	1	48.5	2323.26	1484.10
Built Up	Urban	1.789	1.636	118.1	10120.82	5912.28
TOTAL					**29459.40**	**17895.48**

The savings in fuel usage have been determined using the percentage reductions in Table 9 together with the estimated fuel usage from Table 8. The financial impact of these has been costed using the 1998 cost per litre of fuel (DETR 1999b, Table 2.4) excluding taxes. This

[4] http://www.roads.detr.gov.uk/vehicle/environment/fuelcon/index.htm

gives a price per litre of 12 pence per litre and 11.9 pence per litre for Unleaded petrol and Diesel respectively. Since leaded petrol will not be available from the start of the year 2000 only the price for unleaded petrol has been used. Although Table 1 provides different estimates for urban peak (8%) and off-peak (8.5%) fuel savings, a single reduction of 8% has been used in Table 9.

Table 9: Annual (1998) fuel savings from Mandatory EVSC

Road Type	EVSC Fuel Saving	Fuel Usage (litres)		Fuel Savings 10^6 litres		Non Tax Savings £x10^6	
		Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
Motorway	1%	3884.87	2481.66	38.85	24.82	4.662	2.953
Major							
Non Built Up	3%	6351.83	4057.56	190.56	121.73	22.867	14.486
Built Up	8%	6778.63	3959.88	542.29	316.79	65.075	37.698
Minor							
Non Built Up	3%	2323.26	1484.10	69.70	44.52	8.364	5.298
Built Up	8%	10120.82	5912.28	809.67	472.98	97.160	56.285
TOTAL		**29459.4**	**17895.5**	**2323.26**	**1484.10**	**198.127**	**116.720**

4.2 TRAVEL TIME

The National Travel Survey (DETR, 1999c) contains details of the time spent undertaking personal travel by various modes. The survey does include travel in the course of work or business but only where the purpose of the journey is for the traveller to reach a destination. Work journeys to deliver goods, or to convey passengers are not considered, nor is travel by crews of public vehicles, emergency services or the like. As such the estimates of time spent travelling per person are an underestimate. Furthermore, while the distance travelled reports data for lorry/van drivers and passengers, the time spent travelling as a lorry/van driver is not provided.

It is possible to use this information together with the annual vehicle km travelled to estimate the annual time spent travelling. However this factoring is likely to result in some bias since delivery trips are more likely to be undertaken in loaded HGVs which will travel more slowly. Furthermore it is likely that the personal travel measured in the survey will over represent travel shorter distance travel on local roads with potentially more congestion.

Using the annual total time spent travelling time by car drivers (7826.74 x10^6 hrs per year) and the volume of travel by car drivers (296.188x10^9 veh.km) from Table 10 together with the total volume of travel recorded on all UK road types 459.4 x10^9 veh.km (DETR, 1999b, Table 4.10) the estimated total time spent by drivers travelling on roads is 12139.602 x 10^6 hours per year for 1998, for all motor vehicles. Since many vehicle types e.g. buses, coaches and HGV are limited in their capacity to speed, increased travel time only arises for cars, taxis and light vans. This equates to 10059.18 million vehicle hours or 91.1% of total vehicle hours.

Table 10: Annual travel time and vehicle km 1998

Mode	Per person Total			Population (1998) 55.775 million*	
	Annual Hours#	Annual Miles†	Annual Km	Total Annual hours x10^6	Total Annual veh. km. x10^9
Walk	72	193	308.8	4143.456	17.223
Bicycle	5	38	60.8	287.74	3.391
Private Hire Bus	NR	103	164.8	NR	9.192
Car driver	136	3319	5310.4	7826.528	296.188
Car passenger	81	1973	3156.8	4661.388	176.071
Motorcycle	1	30	48	57.548	2.677
Van/Lorry-driver	NR	178	284.8	NR	15.885
Van/Lorry-passenger	NR	66	105.6	NR	5.890
Other Private	6	35	56	345.288	3.123
Bus (London)	8	52	83.2	460.384	4.640
Bus (other local)	23	197	315.2	1323.604	17.580
Bus (non local)	3	95	152	172.644	8.478
LT underground	5	51	81.6	287.74	4.551
Surface Rail	13	290	464	748.124	25.880
Taxi/Minicab	3	50	80	172.644	4.462
Other Public inc.air	1	57	91.2	57.548	5.087

NR Not Reported
*Source Bulletin on Personal Travel Table 1.1
#Source Bulletin on Personal Travel Table 3.4
†Source Bulletin on Personal Travel Table 3.1

To apportion the total travel time across the road types of Table 1, the general approach has been to develop weighting factors based on the volume of travel on various road types (DETR 1999b, Table 4.10) and the mean speeds reported from the survey of travel speeds on English Trunk Roads (DETR, 1999d; Table 1) and Vehicle Speeds in Great Britain (DETR, 1999e).

The survey of Speeds on Trunk Roads considers peak (07:00-10:00 and 16:00-19:00) and off peak (10:00–16:00) performance. These have been converted to a single flow-weighted mean using factors (55%/45%) derived from a sample of roads in Leeds (Table 11).

Table 11: Volume of travel and mean speed by road type

Road Type		Travel 1000 x10^6 veh. Km	Average Speed km/h (mph)		
			Peak	Off Peak	Mean
Motorway	All	81.1	89.2 (55.7)*	100.3 (62.7)*	94.2 (58.9)
Major Roads	Non Built Up	132.6	82.9 (51.8)*	90.0 (56.3)*	86.1 (53.8)
	Built Up	79.1	44.9 (28.1)*	55.4 (34.6)*	49.6 (31.0)
Minor Roads	Non Built Up	48.5			73.6 (46)[#]
	Built Up	166.6			51.2 (32)[#]

*DETR 1999d Table 1
[#]DETR 1999e Table 5.

In Table 12 the additional travel time by road type has been calculated using weighting factors derived using the distance and speed data from Table 11. The expected increases in travel time have been taken from the micro simulation modelling (Table 1) and where separate values of peak and off peak savings are provided a mean value has been calculated using the same 55/45 split.

Table 12: Calculation of travel time increase

Road Type		Weighting Factor	Annual Travel Time (10^6 hours)	Increase in Travel Time	Additional Travel Time (10^6 hours)
Motorway	All	10.9%	1367.93	0%	0
Major Roads	Non Built Up	19.5%	2447.01	0.4%	9.79
	Built Up	20.2%	2532.48	4.31%	109.15
Minor Roads	Non Built Up	8.3%	1046.97	0.4%	4.188
	Built Up	41.1%	3664.80	4.31%	157.95
TOTAL			11059.18	**2.54%**	281.08

5. COSTS OF EVSC

This Chapter discusses the costs associated with implementing EVSC and presents the basis for and assumptions made in the derivation of the costs associated with the in-vehicle equipment and the associated infrastructure needed to operate the system. Previous deliverables have:

- considered the technical issues associated with system components (D4) and
- investigated of a range of possible implementation scenarios (D6).

Building on this previous work together with the development of a prototype system which was used successfully in the recent field trials (D10), a single system has been selected. The favoured EVSC system, shown schematically in Figure 2, 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 a differential global positioning system (dGPS) together with an inertial gyroscope and dead reckoning capability will position the vehicle on the digital map.
- The relevant speed data will then be read from the in-vehicle map.
- The engine control unit (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:
    - o Engine management and
    - o Active Braking/Traction control

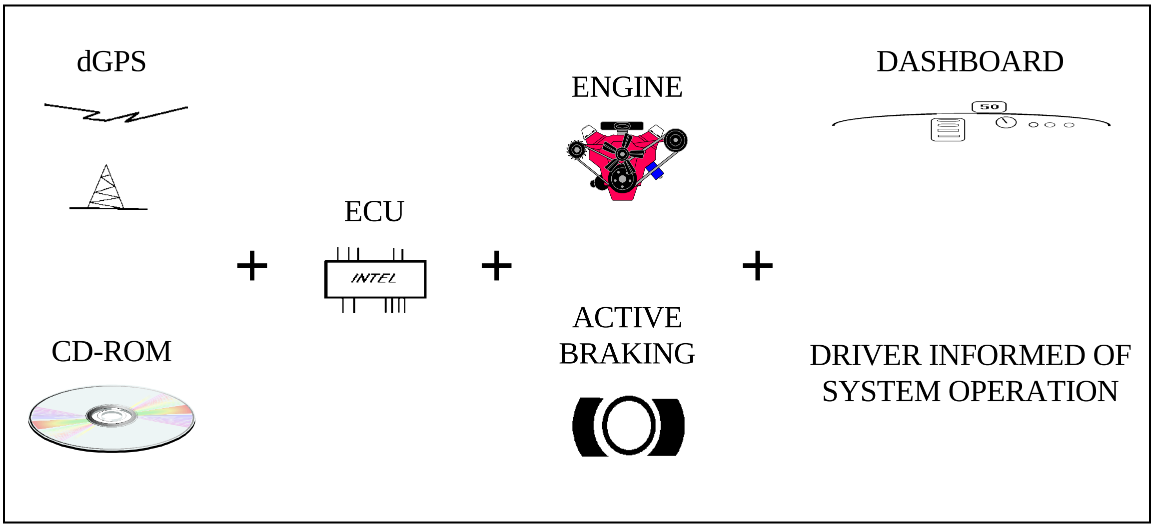

Figure 2: Components of the favoured EVSC system

The digital maps are expected to be updated continuously and issued as part of the annual vehicle licensing procedures. Between revisions update data would be broadcast using a digital broadcast system such as UMTS (the third generation mobile phone system) or DAB (Digital Audio Broadcast). These broadcasts would also be used to provide dynamic speed limit data.   For the purposes of arriving at estimated costs of future systems, this particular implementation of an autonomous EVSC has been assumed. But technologies are changing very rapidly in Intelligent Transport Systems, and the whole area of information services provided via mobile phones is likely to take off very rapidly in the future, particularly with the bandwidth that will be available on the so-called 3rd generation mobile phone system. The new bandwidth may well mean that an on-board physical storage device, such as a CD-ROM, can be dispensed with. Instead, the local digital road map could be downloaded into the vehicle as it arrives in the area. Such systems are already being proposed by navigation system providers, including the provision of current traffic information such as delays on particular routes. Such a configuration would mean that the digital maps would always be up-to-date. The configuration would also mean that there would be little practical difference between Fixed EVSC and Dynamic EVSC, at least as regards the on-board components.

For the moment, however, the costs estimates have been prepared using a configuration of the autonomous architecture, discussed in Section 2.1 of this report, in which the national digital road map encoded with speed limits is stored on board the vehicle. Within this configuration, a number of different products or technologies may fulfil the requirements of each element in the sub-systems. This combined with the uncertainties inherent in estimating the future costs of new technology has lead us to consider generic costs for each element rather than create a multitude of sub-options that are specific to a particular type of unit. In discussing the costs of these systems it is useful to identify three main areas:

- Information Supply,
- System Control and the
- Human Machine Interaction system.

The options available in each of these areas together with the assumptions used to develop the cost estimates are discussed below.

5.1 INFORMATION SUPPLY

The Information Supply System includes all system elements related to providing the vehicle with the current speed limit information, and includes:

- Generation of the digital maps and associated speed limits
- The administrative and material costs associated with providing annual updates
- The costs of broadcasting current update, and dynamic speed limit data
- The storage media and reading capability
- The technology the vehicle requires to locate its position on the map database

5.1.1 Creation of digital maps

Clearly there is a significant cost in creating the digital map. Although developers of in-vehicle navigation systems have done a considerable amount of work in this much of the information sought is commercially sensitive. Our review of other studies has identified only one other UK study (Perrett and Stevens, 1996).

In that study, the cost of constructing a navigation database was estimated to be £25m. Although the basis of this estimate is not detailed, it appears to be equivalent to between

850 and 1250 person years of work to construct the database covering the 366,999 kilometres of road in Great Britain (DOT, 1996b). This level of resources would appear excessive given that much of the trunk road network has already been digitised.

It has therefore been necessary to develop an estimate from first principles. Assuming that:

- 200 people are involved and
- labour represents 50% of the total project cost,

the set-up cost would be in the order of £8m to £12m. This cost would provide both the fixed and variable speed limit maps. However a dynamic system would require additional roadside monitoring infrastructure to determine local conditions such as ice, fog or weather. If sensors:

- are situated at key locations, approximately 5 km apart on the principal road network,
- cost £1000 each (including installation and communications to a central control),

this would add approximately £34m to the system costs.

5.1.2 Maintenance and updating

The maintenance cost for the Fixed and Variable speed limit systems is estimated at £2.25m per annum, based on 75 full time staff nation-wide. These staff would receive speed limit changes (from the delegated authorities responsible for managing the road network), collate and code permanent changes to the speed limit database. These would then be incorporated into the new digital maps and broadcast as updates until the new maps were released.

The broadcasting of update information would be a continuous process since disk updates would not be issued at a specific time but throughout the year. Although the annual costs account for the administration of this system it does not include an item for the transmission of the broadcasts. It assumed that these will be essentially “free transmissions” using the current infrastructure, or the future equivalent.

To estimate the additional costs associated with administering the Dynamic speed limit system, we have doubled the estimated resources. This would provide for 150 persons to manage the sensor network and code temporary speed limits such as those applying to road works sites as well as the changes to the fixed network as part of the annual update/licensing process. In addition to this it is expected that the sensor network would require replacement at a rate of 10% per annum. The unit cost for each sensor is assumed to be around £100 dropping to £10 by the year 2010. A summary of the unit costs for information supply are given in Table 13.

Table 13: Costs for information supply (1998£)

Item	Now	2010
Construct Digital Map		
Fixed Speed Limits	8m	8m
Variable Speed Limits	12m	12m
Dynamic Speed Limits	12m	12m
Sensor Units (Dynamic Only)	34m	31m
Update system information (per year)		
Fixed Speed Limits	2.25m	2.25m
Variable Speed Limits	2.25m	2.25m
Dynamic Speed Limits	4.5m	4.5m
Sensor Units (Dynamic Only)	0.34m	0.034m

5.1.3 In-vehicle components for "knowing" the speed limit

In the vehicle three items are required to allow the data to be used: the reader to read the digital map from the storage, the vehicle positioning equipment and the receiver for the update information.

The exact form of the storage media is currently unspecified although it must be robust and capable of large data storage and high speed retrieval. Possible options include solid state memory units or high-speed CD-ROM and DVD devices.

For the vehicle positioning technology, route guidance and driver information systems which include a complete navigation system including digital maps GPS with gyroscopes and a dead reckoning system are currently available for around £1500. It should however be noted that, although these systems will become everyday items in vehicles, they are currently priced to recoup the technical development cost from a relatively small market penetration. As a result the cost of these systems has reduced significantly during the term of this research.

Costs estimates for all elements of the in-vehicle equipment are shown in Table 14 both for now (2000) and the expected cost in 2010.

Table 14: Unit costs for a CD-ROM based system (1998£)

Item	Now	2010
Data storage	5	1
Reader Unit	300	50
GPS + gyroscope + dead reckoning sensors	800	200
Update in vehicle disk maps per vehicle per year	5	1
Additional costs on vehicle receiver	50	5

5.2 VEHICLE CONTROL SYSTEM

The management and implementation of speed control within the vehicle will be undertaken by the on-board control unit and the retardation system. The on-board control unit will provide the integrated logic to co-ordinate the EVSC control with other vehicle functions. This functionality may be undertaken by a new dedicated unit or incorporated into an existing electronic control unit (ECU). Clearly, as more sophisticated engine management and braking systems are increasingly available, this function will be integrated into the existing engine management system /electronic control unit. Although the cost of developing a separate unit has been estimated (Table 15) it is expected that, with the implementation of EVSC, advanced engine management systems will become standard production items, and a degree of shared functionality would result. Therefore an average present cost of £185 is proposed, reducing to £10 for 2010.

Although the ECU may be used to deliver the initial retardation, the proposed system uses active braking to gently reduce speeds when entering a lower speed limit or to hold speeds to the specified limit on downhill grade. The cost of supplying this active braking component will differ markedly between passenger cars and commercial vehicles. The cost estimates in Table 15 are based on passenger cars, and may be ten times larger for HGVs and buses. However since these vehicles comprise approximately 2.5% of the vehicle fleet the distinction in costs is well within the bounds of the estimates and no further adjustment to the costs has been made.

The cost of an active braking system assumes that in the current year traction control and ABS actuators are required solely for EVSC. It is however likely that by 2010 much of the vehicle fleet will be fitted with traction control and ABS. This allows us to reduce the 2010 cost of this item from £300 per vehicle (assuming that all costs are accrued to EVSC) to £100 per vehicle (assuming a shared functionality). It is also assumed that all vehicles will have fully functional ECUs and the estimates therefore include the cost of updating the ECU software.

Table 15: Unit costs of on-board control unit (1998£)

Item	Now	2010
Cost per unit (separate controller)	300	30
Cost per unit (integrated with existing vehicle ECU)	70	10
Average assuming 50% require separate controllers (now only)	200	10
Active braking including traction control and ABS actuators	1000	100

5.3 HMI

Once again it is difficult to fully rationalise a truly "additional" system for EVSC. The design of the vehicle HMI should seek to integrate all information display and control elements into a whole solution. If speed limit data was required to be displayed then it would ideally be within a display functionality present within the vehicle. For example, highlighting in some way the local speed limit on the speedometer dial via a circle of LEDs or similar mechanism. Therefore the additional costs are likely to be marginal if this is done. The same comments would apply to control of EVSC by switches. This may be done by including this into existing controls thereby making additional costs, shown in Table 16, are minimal.

Table 16: Unit costs of HMI (1998£)

Item	Now	2010
Simple visual and/or auditory displays	1	1
Driver self selected system controls	5	5

5.4 SUMMARY OF SYSTEM COSTS

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. These costs, presented in Table 17, are for both the current estimate year 2000 and for the future year 2010. Linear interpolation is used to establish the costs in any intermediate year. The estimated costs for 2010 will be 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 17: 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

6. COST-BENEFIT ANALYSIS

In the process of economic evaluation the net present values (NPV) of costs and benefits are calculated to provide a measure of the economic viability of the project. For each future year of the project 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. This assumption is valid since the costs associated with black spot treatments, enforcement and educations programmes have not been included in the “Do Minimum” scenario. The annual values for the costs and benefits are then discounted to base year sums, and the ratio of benefits divided to costs is calculated.

For this system:

- Costs include
    - Infrastructure costs
    - Maintenance costs
    - In-vehicle costs
    - Updating costs
- Benefits include:
    - Accident Reductions
    - Fuel Savings

6.1 ASSUMPTIONS

The proposed implementation timetable is discussed in detail in chapter 7 together with the reasoning that underpins the timetable. The key points of this timetable which impact on the economic evaluation are:

- 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[5] 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.

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

The economic evaluation has been undertaken using the following assumptions:

- A discount rate of 6% (DoT, 1996)
- Costs expressed to a base year of 2005 in terms of 1998£
- Forecast growth in travel is based on Transport Statistics Great Britain (DETR, 1999b) Table 4.10 and indexed to 1998
- The value of time used to calculate the impact of travel time increases is that for an Average Car (DoT, 1996)
- The value of travel time and accidents have been considered under the high and low growth scenarios for GDP (DoT, 1996)
- The resource cost of fuel has been projected over the analysis period using the COBA values (DoT, 1996)
- No residual values are assumed at the end of the analysis period.

Our analysis begins by considering the base cases of EVSC and then looks at the proposed implementation strategy.

6.2 COSTS

The discounted costs for both the Advisory and Mandatory EVSC functionality are given in Table 18 and Table 19 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%.

Table 18: 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 19: 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**

6.3 BENEFITS

The benefits of EVSC are the reduction in accidents and the reduction in fuel consumption. 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 safety schemes. However, the travel time values associated with current speeding are provided in the tables showing the discounted benefits to permit calculations with them included.

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. 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 20 each case has been considered using the forecast growth in travel together with both the High and Low forecasts for the rise in GDP.

Table 20: Discounted benefits of EVSC 1998£m

System	Fuel Saving	Travel Time	Accidents		
			Fixed	Variable	Dynamic
Low GDP					
Advisory	1460	(–10420)	17816	18772	25534
Driver Select	1826	(–13026)	17987	19626	31046
Mandatory	3651	(–26051)	35973	39252	62092
High GDP					
Advisory	1625	(–10810)	24673	25997	35361
Driver Select	2032	(–13512)	24909	27179	42994
Mandatory	4064	(–27024)	49818	54358	85989

From Table 20 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.

6.4 BENEFIT COST RATIOS

Combining the costs of Table 18 and Table 19 with the benefit estimates of Table 20 provides a range of benefit cost ratios in Table 21. Clearly a Dynamic Mandatory system provides the most attractive solution under both GDP growth scenarios.

Table 21: 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 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 22).

Table 22: 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.

7. A PROPOSED STRATEGY

7.1 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. 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 Chapter 3 of this report. The predicted impact of EVSC along these two dimensions is shown in Table 23.

Table 23: 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 23 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.

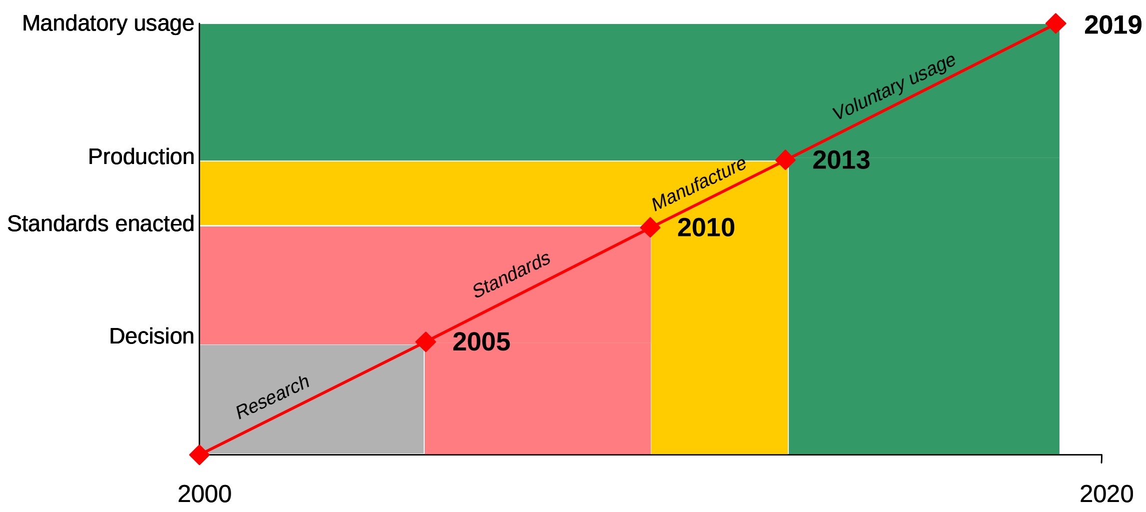

Figure 3: A path to full implementation

Figure 3 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.

7.1.1 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, by for example ECE and CENELEC. 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.

7.1.2 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.

7.1.3 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.

7.1.4 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 reported in Deliverable 11 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.

7.1.5 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.

7.2 BENEFITS AND COSTS OF PROPOSED STRATEGY

The benefit and costs analysis done in chapter 6 is here revised to take into account the proposed timing of the transition phasing 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”.

The question remains as to whether during the phasing in, those drivers who choose to activate Mandatory control through the Driver Select system are more likely to be those in the lower portion of the speed distribution. If this is the case the accident reductions may well be less than anticipated. To test the impact of this possibility four accident assumptions have been tested:

1. No accident benefits are generated during the implementation phase because only slower drivers choose to be controlled by the system and higher speed drivers do not change their behaviour.
2. The system acts as an Advisory system since slower drivers choose to use it while higher speed drivers still receive speed limit advice and modify their behaviour slightly.
3. Half of the drivers use the system irrespective of where they lie in the speed distribution and the other half do not modify their behaviour in any way.
4. Half the drivers use the system irrespective of where they lie in the speed distribution and the other half modify their behaviour in accordance with the speed limit advice.

With the exception of assumption 1, all other options produced accident benefits within a 10% band centred around the values calculated under assumption 3. Although the benefits under assumption 1 were between 10% and 13% less than those calculated under assumption 3, this is considered an extreme state. Given that the impact of these various assumptions is relatively small, the benefit cost predictions have been made using assumption 3. The predicted benefit components for each speed limit system are given in Table 24, disaggregated by phase. The sum of these benefits together with the costs and resulting Benefit Cost ratios are given in Table 25. In Table 25 the value of the travel time loss for previous speeders has once again been excluded from the calculations.

Table 24: Discounted benefits of proposed EVSC system (1998£m)

Phase	Traffic Growth	Growth in GDP	Fuel	Travel Time	Accidents		
					Fixed	Variable	Dynamic
Phasing In (2013 to 2019)	Nil Growth	Low	343	(–1669)	2303	2513	3975
		High	362	(–1730)	2886	3149	4981
	Forecast	Low	451	(–2179)	3009	3283	5194
		High	476	(–2261)	3771	4115	6509
Fully Operational (Beyond 2019)	Nil Growth	Low	1922	(–15231)	21017	22932	36276
		High	2173	(–15788)	29593	32290	51079
	Forecast	Low	2749	(–21693)	29955	32685	51704
		High	3112	(–22503)	42276	46129	72971
Overall	Nil Growth	Low	2265	(–16901)	23320	25445	40252
		High	2535	(–17519)	32479	35438	56060
	Forecast	Low	3200	(–23872)	32964	35968	56898
		High	3588	(–24764)	46047	50244	79480

Table 25: Benefits, costs and resulting B/C ratios for proposed EVSC system

Phase	Traffic Growth	GDP Growth	Total Discounted Benefits (1998£m)		
			Fixed	**Variable**	**Dynamic**
Phasing In (2013 to 2019)	Nil Growth	Low	2646	2856	4319
		High	3247	3510	5342
	Forecast	Low	3460	3735	5645
		High	4247	4590	6984
Fully Operational (Beyond 2019)	Nil Growth	Low	22939	24854	38198
		High	31766	34463	53252
	Forecast	Low	32703	35433	54452
		High	45389	49242	76084
Overall	Nil Growth	Low	25585	27710	42516
		High	35014	37973	58595
	Forecast	Low	36164	39168	60098
		High	49635	53832	83068
Total Discounted Costs (1998£m)			**5366**	**5369**	**5401**
B/C	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.

7.3 TARGET SYSTEM

So far, the discussion of implementation strategy has neglected the *Currency* dimension discussed at the beginning of section 7.1. Table 23 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.

7.4 INSTITUTIONAL, LEGAL AND STANDARDS REQUIREMENTS

7.4.1 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.

7.4.2 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 subsidiarity 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. As discussed in Chapter 5, 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.

7.4.3 Legal issues

The legal issues arising from EVSC are covered in Deliverable 7.2. The report concludes that new arrangements may need to be put in place for Type Approval, and that 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.

7.5 FURTHER RESEARCH

The project has been able explore many of the research issues associated with EVSC. However a number of aspects have not been covered. In behavioural terms, perhaps the most significant issues remaining are those associated with long-term use of EVSC. An aspect that needs to be studied is what are the more long-term behavioural adaptations to the system. For example, the simulator experiments have found some evidence of negative behavioural adaptations in the short term — shorter headways in car following and more risky decisions at junctions. These behaviours could not be confirmed in the on-road studies, because the necessary traffic conditions for observing such behaviours were not available. However, it is possible that these negative behaviours would diminish or disappear with more long-term exposure to EVSC: as drivers became more accustomed to it, they might well become more comfortable with it and learn not to fight it. These issues can only be investigated in the context of longer-term field trials.

Another issue requiring further investigation is driver compliance with a voluntary (Driver Select) system. The general indications from the current project is that compliance is reduced with increasing familiarity, and that drivers tend to disengage the system when traffic conditions do not prevent speeding. Conversely, they engage the system when this has little practical impact. Again, it is not known whether these tendencies will persist with long-term use, and if they do to what level compliance will reduce. Compliance with voluntary EVSC should also be investigated in long-term trials.

Finally, extensive research needs to be carried out, at a national or European level, on the technologies to enable EVSC. There is very rapid change in information and communication technologies and it would be unfortunate if EVSC did not take advantage of newer and more capable technologies and systems as they become available. This applies even to the Fixed variant of EVSC, but is perhaps even more critical for the Variable and Dynamic versions.

8. 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.

9. 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.

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