IMPLEMENTING INTELLIGENT SPEED ADAPTATION IN THE UK: RECOMMENDATIONS OF THE EVSC PROJECT

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SUMMARY

The UK External Vehicle Speed Control (EVSC) project has prepared a proposed strategy for implementing Intelligent Speed Adaptation (ISA) in the UK. This work constituted the final phase of the research project. The strategy is based on an assessment of the most promising system architecture for ISA, on the results from the user trials and simulation modelling conducted in the project, on a review of the benefits and costs of various alternative versions of ISA and on an estimation of the time required from a possible future decision date in order to implement ISA. It is important to note that the project recommendations do not constitute national policy in the UK and that no political decisions have been made to move ahead with the implementation of ISA.

INTRODUCTION

The External Vehicle Speed Control (EVSC) project, funded by the UK Department of the Environment, Transport and the Regions, began in February 1997 and ended in February 200). Its aim was to review a broad range of factors related to the possible introduction of an automatic system to limit the top speed of road vehicles. Phase I of the project was designed as an introductory stage to prepare for the subsequent detailed design and experimental work. Phase II was the main research phase of the project. Its major work was concerned with the delivery of a prototype vehicle, user trials in a driving simulator and on real roads, simulation modelling to predict network impacts of ISA and a review of how ISA could be put into mass production. The last phase of the project reviewed the implications of the earlier work for implementation and prepared a proposed strategy for implementing ISA. In preparing the strategy, the predictions of the safety benefits of ISA that had been made in Phase I were revised as was the cost-benefit analysis. This paper summarises the work on implementing ISA.

SYSTEM TYPOLOGY

An ISA 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 ISA 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.

A third dimension (one that only applies to Voluntary and Mandatory ISA) is the strictness with which the ISA 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.

SYSTEM ARCHITECTURE

When the project began at the start of 1997, the general assumption was that a future national or European ISA system would be based on roadside beacons, probably Dedicated Short

Range Communication (DSRC) beacons. Once the project got underway, the project team discussed the feasibility of alternative system architectures to provide the same ISA 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.

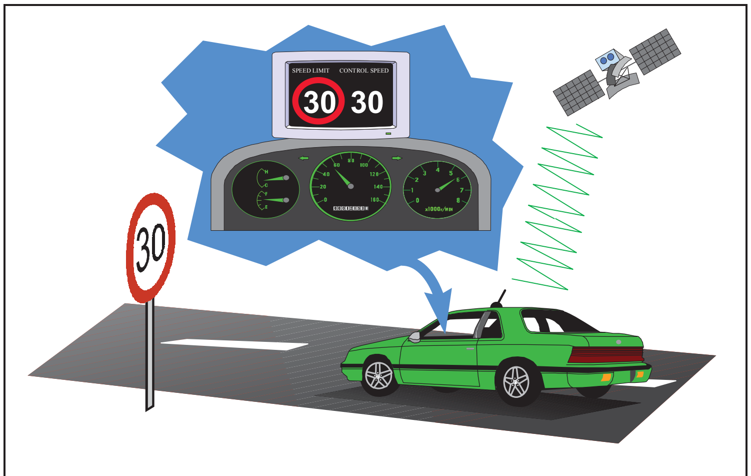

Figure 1: Concept of autonomous ISA system

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 and that a practical demonstrator of this concept had been being built by the University of Lund. The Dutch trial of Intelligent Speed Adaptation in Tilburg is also using the autonomous architecture.

The autonomous architecture is the one that has been implemented in the UK project test vehicle and the vehicle has proved to be a hugely successful demonstrator of this autonomous ISA 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 ISA would be immediate. All equipped vehicles would be provide with ISA 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 ISA 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 ISA 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 ISA-equipped vehicle in the fleet and by the configuration of ISA. A small initial public investment would produce a large benefit.

- The ISA system would function across Europe, provided appropriate digital road maps were available. Germany has indicated that an autonomous and voluntary ISA would be acceptable.
- Purchase of an ISA 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 ISA 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.

PREDICTION OF ACCIDENT SAVINGS

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

The numbers used for the relationship between changes in mean speed and accident risk were that, for each 1 km/h change in mean speed, the best estimate of the change in accident risk was 3% (1). This estimate was applied to create the estimates for **Advisory** ISA. Based on findings discussed in (1), the change in accidents was capped at 25%. For **Mandatory** ISA, 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 derived from (2) and was:

$$y = 0.0139x^2 + 0.0140x$$

where y is relative risk
and x is speed difference of a vehicle from mean speed in mph

Table 1 shows the best estimates of the accidents savings, at various levels of accident severity, for the permutations of ISA. ISA 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 ISA on fatal and serious accidents and on fatal accidents has been made by applying the formula of (3). 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 ISA, the Mandatory Dynamic system, will reduce fatal and serious accidents by 48% and will reduce fatal accidents by 59%.

Table 1: Best estimates of accident savings by ISA 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%

OTHER EFFECTS AND SYSTEM COSTS

Fuel Consumption

Based on the micro-simulation modelling, overall fuel consumption savings with ISA have been calculated. Table 2 shows the resulting savings in fuel consumption with Mandatory ISA and the financial value of those savings.

Table 2: Annual (1998) fuel savings from Mandatory ISA

	Petrol	Diesel
Fuel Savings (10^6 litres)	2323.26	1484.10
Non-Tax Savings (£x10^6)	198.127	116.720

System Costs

As stated above, the favoured ISA system is an essentially autonomous system:

- 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 positions the vehicle on the digital map.
- The permitted speed limit is 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:
    - Engine management and
    - Active Braking/Traction control.

The major costs of this configuration of ISA are associated with:
1. Information Supply,
2. System Control and the
3. Human Machine Interface.

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

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 ISA 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. It is expected that advanced engine management systems will in the future become standard production items, and that there will be a degree of shared functionality between the main engine management system and the ISA system. The additional costs for an ISA HMI are likely to be marginal, since it is expected that future vehicles will have multimode display capability and ISA will require little in the way of extra switches.

For each variant of ISA, it is possible to establish the systems costs in terms of an initial establishment cost to set up the system and an annual cost. Table 3 presents these costs both for an implementation now and for the future year 2010. Linear interpolation is used to establish the costs in any intermediate year. The estimated costs for 2010 are used for all subsequent years. Although this approach represents the reduction of manufacturing costs with respect to time and mass production, costs have not been reduced to reflect the possibility of shared use by other telematics applications.

Table 3: ISA system costs (1998£)

Year	Fitment 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

COST-BENEFIT ANALYSIS

For the economic evaluation of ISA, 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 (4). 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 to costs is calculated. For ISA, costs include infrastructure costs, maintenance costs, in-vehicle costs, and updating costs. Benefits include accident reductions and fuel savings

Assumptions

A set of assumptions has been made about the timings of the events required to implement ISA. 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 ISA is made.
- The analysis period is 30 years from that date.
- The phased implementation would begin in 2013 with new vehicles being fitted with ISA.
- The benefits have been calculated in proportion to the ISA penetration[1] from 2013 through until 2019 when it is expected that fleet penetration will be sufficient (60% or more) that the full benefits of ISA 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.

Costs

The discounted costs for both the Advisory and Mandatory ISA configurations are given in Table 4 and Table 5 respectively. The cost of a Driver Select system is the same as for a

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

Mandatory system since the vehicle functionality is the same in both cases. 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 4: Discounted costs of an Advisory ISA 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 5: Discounted costs of a Mandatory ISA 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**

Benefit-Cost Ratios

The benefits of ISA are the discounted savings from reduced accidents and from reduced fuel consumption. The resulting benefit to cost ratios are shown in Table 6. It is here assumed that fitment of the Advisory version does not include the vehicle control elements required for Driver Select and Mandatory ISA. Clearly a Dynamic Mandatory system provides the most attractive solution under both GDP growth scenarios.

Table 6: Benefit to cost ratios for variants of ISA

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

All the benefit to cost ratios are in excess of 5.0. Mandatory ISA 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.

PROPOSED STRATEGY FOR IMPLEMENTATION

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 ISA will be maximised with 100% fitment.

The main dimensions in ISA deployment are *how intervening* the system should be in operation and *how current* the speed limits themselves should be. It can be seen from Table 1 that the scale of the effect of ISA on safety is larger along the *Intervention* dimension (down) than along the *Currency* dimension (across), although the difference is not huge. Public concern about ISA will also be mainly about the Intervention aspects. In addition, cost of implementing ISA 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.

From the analysis of accident reduction and from the cost-benefit analysis, it can be seen that the clear advantage lies with Mandatory ISA. A strategy has therefore been proposed in which the end goal is mandatory usage in the UK of ISA 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.

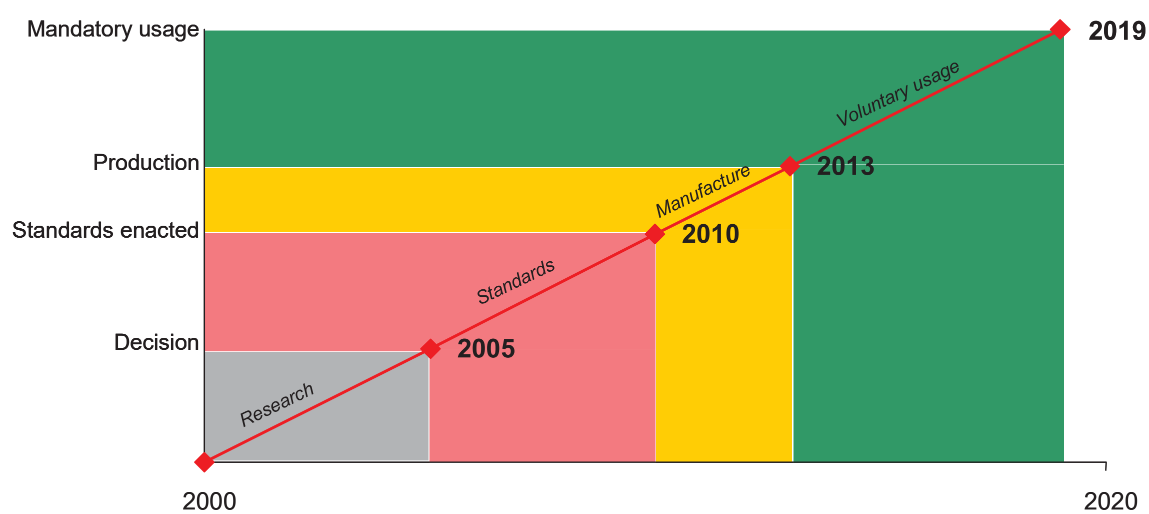

Figure 2: A path to full implementation

Figure 2 shows the major prerequisites and stages to implementing mandatory ISA. 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

This timing is based on the presumption that all the steps are sequential.. The end date could be brought forward if, for example, standards work is begun before the end of the research phase.

Target System

Table 1 shows that the accident savings from the Fixed Mandatory ISA 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 ISA, the goal should be to have the Dynamic capability in operation by 2019.

European Aspects

From a purely *legal* point of view, it may be possible for the UK to move forward with ISA 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 ISA 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 ISA 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 ISA. 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 ISA, as well as the equipment needed on board the vehicle. By then it is likely that new mobile communications systems will 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 ISA, thus making it more attractive to move directly to the Dynamic system.

CONCLUSIONS

A number of significant conclusions emerge:

1. The autonomous (non-infrastructure based) architecture for ISA has significant advantages over the beacon-type system in terms of reliability, flexibility, rapid deployment and reduced public costs.
2. ISA has very large accident-reduction potential.
3. Mandatory ISA is far more effective than advisory or voluntary ISA.
4. The Dynamic variant provides the largest accident reduction.
5. Benefit-cost ratios for all variants of Mandatory ISA are greater than 7.
6. The Mandatory Dynamic system costs little more overall than the Mandatory Fixed system, although the public costs are substantially higher. It therefore has much higher benefit-cost ratios.
7. Given some reasonable assumptions, new vehicles could be equipped with ISA on a compulsory basis by 2013, and this could even be brought forward with some earlier decisions and standards work.
8. 2019 is a reasonable target date for implementing mandatory usage.
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. A Europe-wide system has considerable advantages over a purely national system.

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