# Intelligent Speed Adaptation
# Literature Review and Scoping Study

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# EXECUTIVE SUMMARY

A scoping study was carried out to determine the possible mechanisms for and the likely efficacy of the introduction of Intelligent Speed Adaptation (ISA) in London. The available technologies and research studies are reviewed and the likely safety benefits are presented. A suggested plan for the implementation of ISA in London is presented along with a tentative time-plan.

The research into and deployment of ISA has extended worldwide, and is fast becoming a salient alternative to more traditional speed-reducing measures such as traffic calming and enforcement. With rapid developments in technology, ISA has also become more financially viable; the barriers to implementation are more concerning public acceptability and political will. With regards to acceptance, research studies have indicated that drivers are more in favour of advisory and warning systems and that as systems become stricter in preventing speeding, they become less preferred. In terms of safety benefits, however, stricter systems far outperform those that leave more discretion of the driver. This scoping study suggests that the Swedish model of effective communication and marketing be used prior to the implementation of ISA, in order to create a welcoming attitude. Such a campaign should also highlight the link between speeds and collisions and ISA's potential to reduce speeds and consequently deaths on London's roads, along with the secondary benefits of smoother traffic flow and reduced disruption by incidents in the network.

There is, as yet, no current required procedure for the approval or certification of Driver Assistance Systems such as ISA. It is suggested that ISA systems would appear to come into the category of an Electronic Sub-Assemblies (ESA). Testing of ESAs for compliance is normally carried out by a test house authorised by the Vehicle Certification Agency. In addition, a rigorous safety assessment, using e.g. Preliminary Safety Assessment should be employed to first develop a model of ISA, and then to classify all the identifiable safety hazards.

This scoping study also evaluated the mechanisms for implementing ISA and suggested the best way forward for the London trial. An ISA system requires knowledge of a vehicle's geographical position and the local speed limit, a way of receiving information regarding changes in speed limits and a mechanism for controlling the speed of the vehicle. With regards to position information, using GPS is a far superior solution than that of roadside beacons. For a London trial, the speed limit data will be needed to be collated from the Boroughs and held centrally. A procedure for updates will also have to be put in place. Sweden and Finland will have national digital road maps, incorporating speed limits, this year and Norway already has one. The UK Department for Transport is considering whether to promote such a map, and has awarded a consultancy contract to investigate map issues. In order to actually be able to control the speed of the vehicle there needs to be a link from information to the drivetrain. The level of control over the vehicle can vary from "soft" in which driver inclination to speed is resisted to "hard" in which speeding above a certain point is prevented unless an override is provided. This scoping study and the calculations made for a London trial are based on a system that intervenes and controls the driver's maximum speed.

A calculation of likely safety benefits was made, if a London implementation were to proceed. Implementing Mandatory Fixed ISA (equivalent to getting all vehicles to obey the current posted speed limits) produces a 20% reduction in injury accidents and a 37% reduction in fatal accidents. For an individual vehicle with an overridable intervening ISA (i.e. one linked to the vehicle drivetrain), the predicted reduction in involvement in injury accidents per unit of time is 19.3%.

A number of hardware systems, capable of enacting ISA, were evaluated. No off-the-shelf ISA exists that can be recommended for deployment in London, either due to technical unreliability or implementation difficulties. An approach in which equipment is specifically designed for deployment in London is optimal and recommendations, based on the ISA UK trials are provided. Improvements in data recovery, HMI design and the opt-out function are suggested.

With regards to the creation of the digital road map, Ordnance Survey have already mapped speed signs within the M25 and incorporated them as nodes within the new OS Integrated Transport Network database. Suggestions for verifications and alterations are provided and methods of adding or updating speed limits are covered. In the event that this map is not suitable, an approximation is given estimation the amount of person-time required to develop a new map.

Careful consideration needs to be given to the level of ISA chosen for London. Whilst an advisory system is simpler to implement it is likely it will not have the safety impact of a more intervening form of speed control. It is suggested that three alternative systems could be implemented. The first would be an advisory system for the general market, which simply provided the driver with the posted speed limit. The second would be an enhanced advisory system which incorporated a recording functionality, recording infractions of the speed limit for subsequent use in feedback to the drivers. The third alternative is an intervening ISA with opt-out functionality of the type being used in the current ISA-UK trials. This could be used in the trial fleet and the TfL vehicles, potentially including buses and taxis.

Three different “markets” for ISA are put forward as a means of achieving TfLs current and future road safety targets. First, buses and taxis under TfL regulation could be equipped. Using the predicted 19.3% reduction in collision involvement, ISA could reduce total injury accidents involving taxis by 127, and for buses by 400-500. Second, The GLA group of cars (including TfL’s own fleet) could be included. Cost implications and timescales in relation to this are discussed, however collision reductions could not be calculated. Finally, private motorists could be invited to participate and would provide the largest safety benefits (dependent on system costs, and incentives). A best estimate of unit costs is provided, with all ISA alternatives being under £1000. Incentives for its purchase could include parking, public transport, congestion charge or insurance discounts. An additional study in which a gaming approach (stated preference) was used to elicit Londoners’ willingness to pay is suggested. The safety impact of voluntary adoption of ISA by the general public depends on take-up, but one might expect a baseline of 16 injury accident involvements per 1000 equipped vehicles per year and a reduction of 3 involvements per year with ISA.

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# 1. PROJECT SUMMARY

Transport for London requires a scoping study to determine the possible mechanisms for and the likely efficacy of the introduction of Intelligent Speed Adaptation (ISA) in London. ISA has the potential not only to reduce road casualty numbers but also to optimise network performance. It has the potential to interact with and complement the current congestion charging scheme in London, to create an improved road environment for all road-users.

The important research questions that the team has covered are:

1. What technologies for implementing ISA are currently available, and which are on the horizon?
2. Which of these have been trialled, in what format and in which road environments?
3. What are the approximate unit costs per vehicle for these types of ISA?
4. How can the safety benefits be quantified and were there any additional effects?
5. Was public or user opinion measured, and if so, how did ISA impact on it?
6. Given current knowledge, which technology/system/implementation path would be most appropriate for London?

# 2. BROAD OVERVIEW OF ISA

## 2.1 Background to the ISA innovation

The well documented relationship between speed and collisions (Finch, Kompfner, Lockwood and Maycock, 1994; Taylor, Lynam and Baruya, 2000) has led to the development of numerous interventions that attempt to reduce driver speed. These interventions have traditionally employed the "three Es" of Education, Enforcement and Engineering. Such interventions have demonstrated varying amounts of success, although it is often limited in time and space (Comte, Várhelyi and Santos, 1997). For example, whilst speed humps reduce speed locally, drivers are then free to increase their speed (Pau and Angius, 2001); this effect has also been observed with speed cameras (Keenan, 2004).

Intelligent Speed Adaptation (ISA) refers to an assortment of systems that provide drivers with support in their task of speed control. This support can be achieved via a number of technical solutions, including modifications to the engine control unit (Comte, 2000) or by modifying the accelerator pedal (Hjälmdahl and Várhelyi, 2004). A further variant in the design of an ISA system is the amount of control it exerts over the driver. ISA could be implemented as an *advisory* device which simply reminds drivers of the prevailing speed limit and exerts no control over the vehicle. The next level in control is known as *voluntary* ISA, which limits the vehicle to the speed limit, but allows the driver to override the system. The highest level of control can be termed *mandatory*, and exerts full speed control (usually with an emergency system failure function).

For the past 15 years, researchers have been attempting to evaluate the likely benefits that ISA could have for road safety. Research has mainly concentrated on small-scale behavioural trials which have monitored drivers' interaction with a range of ISA variants. These will be discussed in more detail later in the report. As well as behavioural trials, some research has concentrated on gauging public opinion about ISA, usually in the form of large-scale surveys. Finally, some modelling work has also been carried out to assess the effect of ISA on the road network and on collision occurrence.

### *2.1.1 The pioneers*

ISA was born in France when Saad and Malaterre (1982) carried out their study of driver behaviour with an in-car speed limiter. Actually, they did not really test *Intelligent* Speed Adaptation, because the system did not automatically set the correct speed limit; instead drivers had to set the limiter themselves, and, rather like a cruise control, they could set it as they chose. After that there was roughly a ten-year gap until research on ISA was resumed in Sweden in the early 1990s. There followed a series of projects in Sweden, culminating in the large-scale trial of 1999 to 2001, when there were close to 5000 ISA-equipped vehicles on Swedish roads (Biding and Lind, 2002). Most of these vehicles were equipped with an informative or warning version of ISA, but a few hundred used an intervening system, being fitted with a haptic throttle, whereby the accelerator pedal became stiffer when the speed limit was exceeded. A kickdown function was provided to allow drivers to overcome this resistance.

Britain began its national research in 1997 with the External Vehicle Speed Control project, funded by the Department of the Environment, Transport and the Regions (Carsten and Tate, 2000). This three-year project had a very wide remit. It covered virtually every aspect of ISA, ranging from a review of suitable technologies, through studies of public attitudes and willingness to pay, to simulation modelling to examine side effects in terms of travel time[1] and fuel consumption, and finally to predictions of collision savings and systems costs and benefits. The last task of the project was to propose an implementation strategy. The central aspect of the project work was a set of user trials both on real roads (where driver behaviour could be studied in a naturalistic setting) and on a driving simulator (where complete control over the conditions experienced by the drivers could be assured).

In 1999 to 2000, the second major project funded by a national ministry was conducted. This was the field trial with 20 equipped vehicles in a small section of the Dutch city of Tilburg, which was conducted on behalf of the Dutch Ministry of Transport (Duynstee, Katteler and Martens, 2001). The drivers were residents of an area called Campenhoef, who drove with an ISA car for a total of two months of which the first two weeks were with the ISA system off. Speed limits of 30 km/h were enacted within Campenhoef. The speed limiter also operated on 50 km/h roads surrounding Campenhoef and on two 80 km/h rural roads. The trial used a fleet of identical cars, each fitted with a simple digital road map and a non-overridable ISA, which used fuel restriction (and no haptic throttle) to limit speed. Position was obtained from GPS. The cars were each used by six subjects, so that there were 120 participants in total. An ISA bus was also tested.

### *2.1.2 The second wave*

A Danish project at the University of Aalborg was started in 1998 (Lahrman, Madsen and Boroch, 2001). This project culminated in a set of on-road trials in Aalborg with a warning ISA, conducted between December 2000 and March 2001. Twelve on-board units were manufactured. These used a sophisticated positioning system, akin to a navigation system, in which speed limit was encoded as a road attribute and a combination of GPS, dead reckoning (i.e. calculation of distance and direction travelled) and map matching were used to identify the road that a vehicle was most likely on. The whole municipality, i.e. approximately 1200 km of roads, was covered by the map. The units gave digital voice warnings when the vehicle was speeding. The units were each tested in two vehicles, so that a total of 24 drivers experienced the system (although there were in four cases technical problems that were severe enough that the data could not be used). Each driver drove two weeks with the system off, followed by four weeks with the system on.

Work in Finland, concentrating in particular on a “recording ISA” which can be used in a fleet-based context to identify speeding violations, began in 2001 (Päätalo, Peltola and Kallio, 2001). The system is being tested mainly with taxi fleets. No in-

[1] The increase in travel time, which is potentially a negative benefit, was not included in the cost-benefit analysis, on the grounds that time saved through speeding is an illegal benefit. The exclusion of time saved through speeding is in line with DfT policy.

vehicle digital map is used. Instead speed and GPS position are recorded and subsequently uploaded to a server for matching with a digital road map.

Since 2000, the pace and geographic spread of research on ISA have increased. The ISA-UK project began in 2000, focussing in particular on how drivers behave when using an ISA-equipped vehicle for their everyday driving. Four successive field trials with 20 vehicles are being conducted, with each trial lasting six months. And research on ISA has started to move beyond the original circle of the "Sunflower" (Sweden, UK and Netherlands) and Nordic countries. In 2001 to 2002, there were two projects in Belgium. The first of these, conducted in the City of Ghent, examined the potential for ISA to assist a community in its road safety strategy, especially by replacing more traditional traffic calming (Beyst, 2003). The second project focussed particularly on a technical demonstration of a capability to deliver dynamic ISA as one of a range of in-vehicle telematics services (Kenis, 2003).

More recently, new national projects have started in France, Austria and Norway. The French LAVIA project is somewhat similar in scope and scale to the ISA-UK project, but is notable for having as participants the two major French car manufacturers Renault and PSA (Ehrlich et al., 2003). The two car manufacturers are supplying ten vehicles each for the trials. The Austrian project is studying the combination of an advisory ISA with information on school zones and collision blackspots (Maurer, 2003).

### *2.1.3 Outside Europe*

In the last few years, the ISA concept has spread across the globe. In Australia, the TAC SafeCar project is examining a number of vehicle-based safety functions, one of which is ISA (Regan et al., 2001). In Japan, the Soft Car project, funded through a millennium award, moved from a concept of indication speeding to other drivers by means of lights in a vehicle's rear window to a concept that is essentially that of ISA (Oguri, 2002). Canada has expressed its intention to carry out research on ISA (Transport Canada, 2003) and is carrying out trials with an advisory system.

China too has applied the ISA concept. The South China Morning Post of 22 June 2002 featured a story about the municipal buses of Shanghai being fitted with black box recorders which had been programmed with the maximum speed for a given route. These devices sounded an alarm bell when that speed was exceeded.

### *2.1.4 From research to deployment*

Some countries are starting to shift gear from carrying out research on ISA to actual deployment. For example, Sweden is taking a number of steps to promote ISA. Vehicles of the Swedish National Road Administration are to be equipped with ISA. A new PDA-based technical platform for ISA is being developed and this will incorporate a capability to acquire speed limit information over a mobile phone link. A national digital road map, incorporating speed limits, is almost complete, and a national strategy for implementation of ISA is being prepared (Schelin, 2003). Cooperation has been secured with highway authorities so that they provide notification of changes to speed limits.

And, while Sweden is moving from research to deployment, Norway appears to be skipping the research phase and moving straight to deployment. The Norwegian Public Roads Administration (NPRA) is conducting an ISA demonstration project in Karmøy, a community of 40,000 on the west coast. The project has a particular focus on reducing collisions involving young drivers. There are 500 new drivers each year in Karmøy, and the aim is to give 200 of them ISA equipment (an intervening system) on their cars, each year so that there would be 1000 ISA-equipped vehicles after five years. The four other regions of NPRA will follow a similar programme. Thus a substantial proportion of young drivers in Norway will accumulate their early driving experience in ISA cars. A digital road map of all Norwegian roads, with speed limit information, already exists.

Japan too is considering mass deployment of ISA, on an even bigger scale than Norway (Terezaki, Iso and Kurata, 2003). A small trial has taken place in Toyota City of applying the VICS (Vehicle Information and Communication System) system for supplying speed limit information inside the vehicle and warning drivers when they are speeding. VICS uses infrared beacons to transmit traffic information from roadside to vehicle and almost 8 million on-board units have been sold. The test, carried out by the National Police Agency of Japan, focussed on the technical feasibility of the application and on HMI (human machine interface) aspects. It is apparently the intention of the National Police Agency to proceed to a larger trial to confirm the effectiveness of the system in modifying driver behaviour. Should that trial be a success, full national deployment will follow. The agency does not appear to be aware of ISA work elsewhere, but this system is advisory ISA in all but name. And it has the potential to be an ISA system operating on a massive scale.

Thus it can be argued that ISA has now grown up. Over a period of some twenty years, it has, in the words of Claes Tingvall, the Road Safety Director at the Swedish National Road Administration, grown from being regarded as “pure idiocy” to gaining widespread acceptance among road users, public authorities and the private sector (Swedish National Road Administration, 2001). It is no longer merely the brainchild of a few eccentric academics, and it is even generally accepted by many in the car industry that the implementation of ISA is inevitable. An overview of research trials on ISA can be found in Appendix 1.

## 2.2 Comparison to other methods of speed management

This section will summarise the effects of speed management techniques, other than ISA. The purpose of this section is to highlight the potential advantages that ISA has over techniques such as speed humps, safety cameras etc. Only those measures which are highly relevant or already implemented within Greater London will be presented.

### *2.2.1 Speed humps and tables*

Speed humps provide drivers with clear physical feedback to encourage lower speeds. Speed humps can have a circular profile (round-top) or a flat-top with ramps up to the plateau. The most effective height of speed hump has been found to be between 75-100 mm (Webster and Layfield, 1993). Engel and Thomsen (1992) attributed speed humps with the speed reducing effect of 1 km/h reduction in speed for every 10 mm of height of the hump. Hence a hump of a height of 100 mm will produce a speed reduction of 10 km/h. However, due to passenger discomfort, 100 mm humps are not usually suitable for bus routes or where the emergency services may need access.

With regards to collisions, Elvik and Muskaug (1994 – cited in Várhelyi, 1996) reported that speed humps reduced the number of injury accidents by between 25 and 55%. Elvik, Borger and Vaa (1996 – cited in Várhelyi, 1996) based on four different studies in England and Norway, concluded that humps reduced the number of injury accidents by between 51 and 68%.

One common concern with measures such as speed humps is that they cause accident migration whereby traffic is redistributed to alternative routes. No accident increase on such alternative streets were found in the studies cited above. In a study that also compared upstream and downstream speed at traffic-calmed areas, no evidence of downstream increases in speed was found (Barbosa, 1995).

Another concern is that the installation of speed humps encourages increased accelerations and brakings between the humps. This could cause problems for nearby residents in terms of both noise and pollution (Harris, Stait, Abbott and Watts, 1999). Measuring speed before and four weeks after the installation of humps in Gothenburg, Pettersson (1981 – cited in Várhelyi, 1996), showed that the mean speed at the humps was reduced from 45 km/h to 20 km/h but that the speed profile was very uneven. If the distance to the next hump was 100 m or more, drivers braked just before the humps and accelerated after them by 10-15 km/h. About 100 m after they passed the last hump, the mean speed was at the same level as before the introduction of the measures. Speed measurements two years later showed that the effects were stable. It was suggested that to achieve an average speed of about 30 km/h between humps, the distance between them should not exceed 85 m. Pau and Angius (2001) report that the effect of speed humps on driver behaviour is restricted to 20-30 metres before and after the hump. Even more worrying is that some research suggests that drivers have found that increasing their speed reduces the magnitude of the vertical acceleration thus producing a significant reduction of the effectiveness of such devices (Watts, 1973; Kassem and Al-Nassar, 1982).

Speed tables are often used as an alternative to speed humps. Speed tables are flat-topped humps extended at intervals across the width of the carriageway to provide a level path, at the same height as the pavement, for pedestrians to cross. Speed tables thus have the twin advantages of physically slowing down the traffic and also making it clear that pedestrians are present. European experience has shown that a 50 m interval is the optimal spacing to restrain speed (Bowers, 1986). It has been observed though that drivers sometimes ‘gutter run’ to minimise the effects of vertical alignment measures by aligning one side of the vehicle with a gap in the device (typically such devices terminate before the gutter to enable drainage).

It therefore seems that both humps and tables, although effective in their immediate location, may have undesirable side effects that could impact on both safety and emissions. There have also been reports of noise disturbance for local residents (Harris, Stait, Abbott and Watts, 1999).

### 2.2.2 Chicanes and narrowings

Chicanes, or lateral displacements, are designed to encourage drivers to slow down by forcing them to change their direction of travel. The research on chicanes is contradictory. A trial with chicanes in Malmö, Sweden, showed that the mean speed at the measures decreased from 50 km/h to 35 km/h, but conflict observations indicated a reduction in traffic safety (TSV, 1985 – cited in Várhelyi, 1996). Engel and Thomsen (1992) found that a double lateral dislocation on Danish residential streets reduced speeds on average by 4.7 km/h, and a single lateral dislocation by 2 km/h. Again some negative effects at the narrowings arose when vehicles attempted to arrive first (and thus pass first).

It is logical that narrowings will only slow drivers down when there is an oncoming car that is likely to arrive at the narrowing at the same time. On some roads this is not a common occurrence. Thus the effectiveness of road narrowings can be enhanced by the addition of vertical elements such as trees and lamp standards, the combination of which is often called a ‘gateway treatment’ (Bowers, 1986). He also suggests that the optimal configuration for the installation of “slow points” should create 45º changes in direction of the carriageway approximately every 50 m with an offset of the full width of the carriageway.

It appears that in order to induce speed changes, the lateral displacement has to be relatively severe. Barbosa, Tight and May (2000) compared the speed profiles for a number of traffic-calming measures, including chicanes and reported that the more aggressive and constraining measures were effective at reducing speeds. However this severity can lead to possible conflicts between vehicles as drivers attempt to negotiate them. As a result, conflicts may result when road users, in order to maintain the same level of driving performance, do not adapt their speed to the decreased road width (Jacobs, 1976; Lamm, Choueiri and Mailander, 1990).

### 2.2.3 Rumble strips

Rumble strips are widely used as a means of alerting drivers (by increasing arousal) to hazards such as junctions and bends in order to achieve reductions in speed. Many different devices and arrangements have been used, generally bands of coarse surface texture (rumble areas) or narrow strips of material (rumble strips) are laid across the carriageway. Rumble strips, besides the visual stimulation, also give auditory and tactile stimulation that are intended to alert the driver.

Some success has been reported using rumble strips. Webster and Layfield (1993) assessed rumble strips and rumble areas at 35 sites in the UK and found that at most of the sites a small reduction (approximately 6%) in 85$^{th}$ percentile speed was demonstrated after the rumble strips had been installed. However there was evidence to suggest that the initial speed reduction diminished with time. Reductions in mean speeds were slightly higher than reductions in 85$^{th}$ percentile speeds suggesting that faster drivers may maintain or increase their speed at some sites to lessen the “cattle-grid” effect. The authors concluded that rumble devices need to be sited as close to the possible hazard as practical since the speed reducing effect of the rumble device decreases as the distance from the last rumble area increases.

It may be that the main effect of rumble strips is an alerting one. They are traditionally used as a divider between the inside lane and the hard shoulder on motorways and have been found to be successful in reducing the number of run-off-the-road incidents (Griffith, 2000; McCartt, Rohrbaugh, Hammer and Fuller, 2000). In Portugal, Ribeiro and Seco (1997) experimented with various patterns and spacings of rumble strips at nineteen uncontrolled, marked pedestrian crossing points. They found no reductions in speed but collisions involving pedestrians decreased overall in the city during the period of the study. Elvik et al. (1996 – cited in Várhelyi, 1996), synthesised the findings from several studies in different countries on the effects of rumble strips on the approaches to junctions and concluded that they reduced the number of injury accidents at the junctions on average by 33%.

A common criticism of rumble areas is the noise they generate. Gupta (1992) carried out a study in the U.S. that aimed to establish policy standards on the design and placing of rumble strips and to study the noise levels associated with each type of rumble strip. Seven sites were identified and a combination of design parameters including spacing of pads, width of strips and groove pattern selected and measurements of speed and noise levels inside and outside vehicles were taken. The results showed that noise levels inside vehicles rose between 5 and 10 dB and had a positive effect on drivers such that a speed reduction of 16 mph within 600 ft of the first rumble strip was seen. The increased outside ambient noise however drew strong opposition from nearby residents.

Some form of behavioural adaptation has also been reported in areas where rumble strips are placed. If rumble strips on a two-lane road are used only on one side of the road an adverse effect, in the form of swerving into the oncoming lane, can occur. This kind of effect was found by Parsonson and Rinalducci (1982), who suggested that rumble strips should be reserved for non-residential areas where unfamiliar drivers are numerous. On the other hand, full-carriageway devices generate extra noise from traffic travelling in the opposite direction. Petterson (1976) also points out that the alertness-increasing/surprise effect can be lost if rumble strips are used in too many places, especially if the share of local traffic is high at these places.

### *2.2.4 Mini-roundabouts*

Mini-roundabouts were originally introduced as replacements for priority junctions, often to improve operating efficiency by altering the balance of priority in favour of the dominating streams. Varhelyi (1993) describes a large-scale experiment with mini-roundabouts in a Swedish town. On average, the roundabouts reduced speed from 48 km/h to 35 km/h at junctions, with decreases in speed on the links between the roundabouts. In addition, injury accidents at the roundabouts decreased by 44%.

Summersgill (1989) reviewed the accident frequencies and rates of all roundabouts with a central island diameter less than 4 m and concluded that mini-roundabouts are a relatively safe form of junction. This may be because roundabouts are effective in breaking up long lengths of road that otherwise might encourage speeding. Lynam, Mackie and Davies (1988) also found that roundabouts were successful at reducing vehicle speeds and breaking up the perceived straightness of the road. Herrstedt (1992) suggests that roundabouts can be effective speed management tools but their effectiveness is mediated by the extent to which drivers are forced into a roundabout manoeuvre, i.e. deflection. A large roundabout used to mark the entrance to a small town was successful at reducing traffic speeds, whilst a mini-roundabout did not reduce speeds to an appropriate level.

In summary, although mini-roundabouts were originally designed to improve traffic flow through intersections, they have been seen to improve safety by decreasing speeds and associated conflicts. Again, as with the lateral displacements discussed above, the reductions in speeds are more noticeable with increases in the lateral movement the vehicle must undertake.

### *2.2.5 Speed detection and enforcement*

Local authorities have deployed speed cameras in areas where there is a demonstrated speeding and accident problem. Only a small number of well controlled studies have been reported in the UK, the largest of which is the West London trials. These trials were launched in 1992, with cameras placed at sites having a high incidence of speed-related collisions. Early results were promising in demonstrating success in deterring drivers from travelling at very high speeds. The number of drivers travelling at 60 mph or higher in a 40 mph zone reduced by 97% (Swali, 1993). It was also claimed that collisions were reduced by 22% overall and fatal and serious casualties by 38%. The author reported that mean speeds were reduced by 5 mph and 85$^{th}$ percentile speeds reduced by 7 mph. These are broadly in line with the TRL estimate that a 1 mph reduction in mean speed is likely to result in a 5% saving in collisions and a 7% reduction in fatalities (Finch et al., 1994). However a subsequent press report (Local Transport Today, 1996) suggested that speed cameras may bring about only a temporary reduction in collisions.

A New Zealand study compared the effectiveness of overt versus covert enforcement (Keall, Povey and Frith, 2000). Visible speed cameras were clearly signposted, whilst hidden ones introduced some uncertainty as to their location. The authors report statistically significant decreases in mean speed and collision rates. They state that hidden cameras had more of a general effect than the visible cameras which, unsurprisingly, were only effective in their vicinity.

In 1999, a national project board was set up to oversee the introduction of a cost recovery system for speed cameras in the UK (Department for Transport, 2003). Eight areas were selected using including fixed site, mobile and digital cameras. As part of the pilot, each area was asked to conduct speed surveys at camera sites before installation and then periodically after. The vast majority of sites demonstrated a reduction in speed, with average speed across all sites dropping by around 10% or 3.7mph. The speed reduction was more noticeable at fixed camera sites, where the number of vehicles exceeding the speed limit dropped by 67%, compared to 37% at mobile sites. Urban roads saw the biggest drops with average speeds falling by 12-13%. Casualties were also reduced — on average, killed and serious casualties fell by 65% at fixed and 28% at mobile sites.

Current DfT rules (Department for Transport, 2004)for selecting fixed speed camera sites under the national scheme under which offenders contribute to the administrative costs of running the cameras are that:

- The road length in question be between 0.4 and 1.5 km
- At least 20% of drivers exceed thepeed limit in non-congested periods

- There be at least four collisions in which someone was killed or seriously injured in a 36-month period

The most recent evaluation of the national safety camera programme concluded that it had produced a 33% reduction in injury accidents and a 40% reduction in fatalities and serious injuries at sites equipped with speed cameras (Gains, Heydecker, Shrewsbury and Robertson, 2004).

Enforcement or the threat of enforcement appears to be one of the most effective speed reducing measures. However, at mobile enforcement sites the reductions in speed can be short-lived and at fixed enforcement sites drivers are able to learn the position of the cameras and thus may continue to speed away form the sites. Such information about the locations of cameras is even available on the Internet, and discussion forums exist whereby information is exchanged concerning their locations. The obvious cost of enforcement, both in installing and maintaining the cameras and personnel costs, has an important part to play when calculating the cost/benefit ratios of such schemes.

### *2.2.6 Could ISA be the solution?*

In considering this question, we should be quite clear about how existing measures do not provide a satisfactory solution.

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| The measures outlined in the sections above, all have one thing in common – that is their effect is limited in time and space. They may be able to reduce speeds at collision hotspots but their ability to affect speeds globally within the Greater London area is questionable. |
| ISA is global. Its effect is only limited by either the (geographical) size of the digital road map or by the physical positions of the entry/exit beacons. |

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| Traditional measures often contribute to visual clutter. Additional signage and road markings not only have financial implications relating to their installation and maintenance but can cause offence to local residents. |
| ISA is invisible. The only implication for infrastructure is the siting of beacons (if used). These can be mounted on lampposts for minimum visual intrusion. |

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| Traditional measures are not flexible and cannot take into account time of day, day of the week etc. |
| ISA can be dynamic. For example lower speed limits can be enforced during the school-run time, in the vicinity of the school only. In school holidays etc. the limits can be returned to normal. Weekend and off-peak regimes can also be applied. |

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|---|
| Measures such as speed humps still "punish" law-abiding drivers. They are still an inconvenience even when travelling at the appropriate design speed. |
| ISA is silent. It is a support system that does not intrude until the maximum allowable speed is reached. It does not affect the acceleration performance of the vehicle, only its top speed. |

Of course ISA will never be a panacea for the problems of speeding nor will it replace all infrastructural measures to improve flows and calm traffic. TfL should be aware of the following drawbacks:

- ISA will not be able to tackle the issue of “inappropriate speeding” below the speed limit. However, as in the “do-nothing” scenario, the driver is responsible for his or her speed, even if below the posted speed limit. The same would apply with an ISA implementation, even if the speed limit was reduced locally from say 30 mph to 20 mph.
- Modelling has shown that ISA has a general effect on *all* vehicle speeds when penetration rates within the vehicle fleet reach approximately 60%. A small number of equipped vehicles will not make a huge impact on global safety. At 60% penetration, a critical mass is reached, whereby unequipped vehicles are heavily influenced by equipped ones. No trial has yet reached this 60% penetration.
- Some research suggests that safety-conscious drivers will be the first to volunteer to have systems such as ISA installed. Whilst commendable (and certainly should not be discouraged), the greatest benefit of ISA will be seen when it is used by those who engage in a high proportion of excessive speeding. An ISA programme specifically targeted at such drivers has not been carried out to date.
- There will always be an area “outside the zone” where ISA is not available. This may have one of two effects on a driver. Having ISA may induce improved adherence to the speed limits – as a kind of learning effect. On the other hand, once outside the zone drivers may use the opportunity to make up perceived lost time, or simply engage in thrill-seeking behaviour. It is currently impossible to speculate which of the two scenarios is more likely. However, the Swedish ISA trials in Lund did show the latter effect.

## 2.3 Current public and user opinion: the acceptability of Intelligent Speed Adaptation

In 2003, 87% of U.K drivers interviewed as part of the SARTRE 3 study (Cauzard, 2004) agreed that ‘driving too fast’ was a contributory factor to collisions. However, speeding is still viewed as the norm and construed as a ‘non crime’ (Corbett, 2000). The potential of intelligent transport systems to reduce speeds on our roads has therefore received considerable attention in the last 10 years. Although early studies in the U.K involving focus groups with members of the general public, pressure groups, commercial stakeholders and the police indicated a general resistance to the concept of ISA (Carsten and Fowkes, 2000), opinions amongst U.K drivers appear to have shifted in recent years. In 1997, publicity campaigns and education were deemed more suitable methods to change poor safety attitudes and an increased police presence was desired (Carsten and Fowkes, 2000). Since then however, several surveys of the general public have reported more favourable attitudes towards ISA systems.

A survey of 2000 UK car drivers aged 17 and over carried out in 2001 by MORI Financial Services on behalf of jamjar.com (MORI, 2001) suggested that 51% of drivers would approve of the compulsory fitting of speed limiters on all cars to prevent speeding. Moreover, they report that nearly 13 million drivers (43%) would approve of speed limiters being fitted to their own car. However, only 34% of those who admitted driving at a speed of 100mph approved of fitting the system to new cars and males (41%) were less likely to approve than females (66%) suggesting that those in most need of the system were unlikely to accept and use it. Another study conducted by MORI on behalf of the FIA Foundation in 2002, went onto suggest that over 70% of people supported an audible in car warning system or dashboard display that alerted them to legal speed limit on residential roads and trunk roads in built up areas. Indeed, 58% of the respondents supported having compulsory in car speed limiters in 30mph zones if this resulted in the removal of speed humps (MORI, 2002). The SARTRE 3 study reported that 34% of U.K drivers regarded ISA as very useful and 37% stated they were very much in favour of ISA.

Nevertheless, as Carsten (2002, p 7) points out, these attitudes may not be "deeply held" and without gaining strong public support the uptake of ISA is likely to be low and political backing weak. The successful launch of an ISA system will ultimately rely upon general public acceptance. However, in order to maximise acceptance we must first understand the individuals' experience of ISA and secondary benefits and disbenefits associated with the use of these systems.

### *2.3.1 Secondary effects of ISA*

A fundamental criticism of ISA has been that of the drivers' loss of control of the driving situation. Opponents suggest that this type of technology, runs the risk of taking the driver 'out of the loop'. However, whilst research has examined the negative behavioural effects of ISA, it is the drivers' ***perceived control*** that influences individuals use and acceptance of ISA. Lahrmann, Madsen and Boroch's (2001) investigation of an advisory ISA system using on road trials with 24 Danish drivers, noted, however, that drivers did not feel that ISA had limited their freedom. Similarly, a Dutch field trial in the city of Tilburg using 20 vehicles with a mandatory system controlled by means of fuel restriction, also found that only 10% of all car drivers, test drivers, residents of the test area or car drivers outside the test area argued that loss of freedom and unwelcome control was an obstacle to implementation (Bessling and van Boxtel, 2001). Perceived control could obviously depend upon the level of control imposed by an ISA system. The results here however, indicate that neither passive nor intrusive systems significantly limit drivers' perceived freedom.

Several studies have in fact noted a number of secondary benefits associated with ISA. Almqvist and Nygard (1997) found that although some drivers considered overtaking to become more dangerous, three quarters of the drivers felt that interaction with other drivers had become safer. The twenty five drivers who had a haptic throttle system fitted to their own vehicle for two months, felt that, whilst the distance to the car behind had become shorter, the distance to the car ahead had increased. Indeed, 80% believed that, at that time, the traffic was safer when ISA was employed. These thoughts were confirmed in the Tilburg trial. When asked about the arguments that favoured the implementation of ISA, 52% of the drivers agreed that ISA increased pedestrians and cyclists safety and 36% agreed ISA was safer for the driver (Bessling and van Boxtel, 2001). The largest ISA study to date also highlighted this apparent increase in ***perceived safety***. The Swedish National

Road Administration conducted a study in four different towns involving up to 5000 cars and more than 10,000 drivers. A number of variants of ISA were tested (warning, advisory and haptic throttle). Prior to taking part in the Swedish ISA trial, 40-60% of drivers believed that ISA would increase their own traffic safety and although this dropped to 25% after the first month of the trial, responses rose again to 40% (Biding and Lind, 2002). Moreover drivers clearly perceived that they had become better drivers as a result of ISA, presumably because they felt that increased speed compliance and made them safer.

Similarly, in Lahrmann, Madsen and Boroch's (2001) study, two drivers who had frequently exceeded the speed limit in the past suggested that the advisory ISA system had a ***calming effect*** on their driving. This effect was also reported in the Tilburg trial. Here, 25% of test drivers noted that when driving within the enforced speed limit they slowed to speeds below the limit (Bessling and van Boxtel, 2001). Test drivers rarely drove continuously at the speed limit suggesting that ISA had imposed a calming effect upon driver style. A successful implementation strategy would therefore seem to benefit from emphasising the positive feelings associated with engaging in pro safety behaviour.

ISA has also been shown to improve drivers' ***attention***. Almqvist and Nygard (1997) reported that 80% of test drivers using a haptic throttle system, felt they drove in a more attentive manner. The authors suggest this may be because the drivers were no longer forced to concentrate on the speed limit. Comparable findings have been demonstrated with a warning system, when drivers stated that they were more aware of their speed following experience of ISA (Lahrmann, Madsen and Boroch, 2001). Test drivers in the Swedish trial also agreed that ISA increased their attention to vulnerable road users (Biding and Lind, 2002).

Despite these psychological and behavioural benefits however, drivers have expressed some concerns regarding the impact of ISA upon the driving experience. In the Swedish trial, 30% of drivers in Borlänge (advisory ISA) and Lund (Active gas pedal) and 20% of drivers in Lidköping (advisory and active gas pedal) and Umeå (warning system) reported increased ***irritation*** when driving with ISA and this increased over time (Biding and Lind 2002). The authors suggest that technical difficulties may account for this irritation and indeed, other measures incorporated within the study suggest that it has not been more taxing driving with an ISA system (except perhaps for the active gas pedal).

However increases in frustration levels were also observed and other studies have noted similar reports of annoyance and irritation. When interviewed, Finnish drivers reported increased mental demand, time pressure, effort, frustration and insecurity when driving a mandatory ISA system (Päätalo, Peltola and Kallio, 2001). In a comparison of three countries (Spain, Sweden and the Netherlands), 60% of drivers also reported that an active gas pedal system was more stressing than driving without the system and 45% suggested that the pedal negatively affected their patience (Várhelyi and Mäkinen, 2001). However, results were affected by responses from an overwhelmingly young male Spanish sample and the Swedish and Dutch drivers responses tended to be relatively neutral. More encouragingly, Persson, Towliat, Almqvist, Risser and Magdeburg's (1993) early investigation of a haptic throttle system, observed that drivers with experience of the ISA system did not generally express feelings of being hindered or stressed. Experience would indicate therefore that it is vital a highly reliable system is developed before entry to the market. Frustration may also be reduced once ISA becomes common, i.e. once it loses its novelty effect and once a large number of drivers are subject to the small loss of time consequent on have an ISA-equipped vehicle.

Technical difficulties will undoubtedly lose public confidence and severely affect system use. HMI issues must be fully tested to ensure that the system is usable and causes minimal irritation. Indeed, other countries have observed sabotage of their systems as drivers attempted to mute the warning signals (Umeå trial, Sweden).

These results provide some information regarding the potential secondary benefits/losses of an ISA system. However, given that each country has developed ISA systems with differing functionality and tested these on networks with different characteristics, it is often difficult to compare the potential of each variant of ISA. To date only a few studies have made direct comparisons of different ISA systems. In an early study Almqvist and Towliat (1993) set up a 35km route around Lake Aspen with transponders set up to transmit information regarding the actual speed limit and hazards such as dangerous curves, pedestrian crossings etc. The study compared an advisory system which provided information about the speed limit and also recommended speed choice for certain road conditions and a mandatory style cruise control system which kept drivers' speed to the posted speed limit by the electronic gas or brake unless the driver overrode the system. The advisory system was deemed particularly useful when driving on unknown roads and only one of 15 test drivers expressed a negative attitude towards the mandatory system. However drivers did express concern regarding the cruise control nature of this system noting that they felt uncomfortable travelling at the speed limit in urban areas or on curves and would have preferred better control to reduce their speed.

In Australia, Mitsopoulos, Regan and Tierney (2001) compared an advisory and mandatory system and confirmed the attractiveness of being informed of the speed limit of the road. Despite some misunderstandings regarding the functionality of the system, the systems effectively reduced drivers speed. Surprisingly, many drivers preferred the mandatory system which provided a haptic warning as the active feedback forced them to reduce their speed. Their study also examined a speed request system which displayed the current speed limit of a road when the driver pressed a button. Drivers were positive in their evaluation of this system and considered it particularly useful on rural roads where speed limit signs were less common providing support for the individuals need for speed information.

Päätalo, Peltola and Kallio's (2001) comparison of three systems was less positive and suggested that although drivers sometimes found the advisory system welcome, it was often too rigid and the voice signal was annoying. Moreover, the mandatory ISA system was construed as very irritating and dangerous. Although drivers felt it was an effective speed management device, they worried about their ability to 'get out of the way' of danger and the risk of rear end collisions. Only the recording ISA, a system which showed the driver how much they had been speeding (by means of a percentage bar chart) and did not exert any control was deemed desirable. Biding and Lind (2002) confirmed that informative and warning systems were most preferable by test drivers and the general public prior to the trial. The order of preference for systems was warning, informative then active gas pedal but the differences were marginal. Similarly, U.K simulator and on road studies also suggest that drivers prefer an advisory system to a mandatory system (Carsten and Fowkes, 2000). When considering implementation of such systems it seems important therefore to weigh the relative safety benefits of each system with the associated obstacles to acceptance.

Nevertheless, despite differences in drivers' appreciation of these variants, the studies have, on the whole, found reasonable support for the potential of ISA. Lahrmann, Madsen and Boroch (2001) found that only two drivers expressed defiance and increased speed. Sixty-five percent of test drivers in the Tilburg trial supported the idea of ISA with only 30% of other reference groups (e.g. residents) opposing the concept (Bessling and van Boxtel, 2001). Várhelyi and Mäkinen's (2001) investigation of an active gas pedal across three countries reported that 30% of their test drivers supported the mandatory introduction of ISA with only 11% of drivers completely against the notion.

It is also encouraging to note that familiarity with these systems, generally, breeds acceptance. Simulator and real road studies conducted in the U.K found that driver's judgements of usefulness and satisfaction with the systems generally increased with experience and suggested that drivers were most positive about the "social" rather than "personal aspects" of the system (Carsten and Fowkes, 2000). After experiencing ISA for several weeks 63% of the drivers in the Tilburg trial were positive or very positive towards ISA and only 10% of drivers were negative. In one of the earliest studies, Persson, Towliat, Almqvist, Risser and Magdeburg (1993) also noted that acceptance of ISA increased with experience of the system. In their investigation of a haptic throttle system, 75 drivers aged 25-75 yrs completed a 18km test route with a posted speed limit of 50km/h and 70km/h three times. Comparisons were made across groups that had no experience of the system, had only one drive with the system and with those who completed two drives with the system. Whilst two-thirds of drivers with experience of the ISA system viewed the potential of the system for drivers and vulnerable road users positively, those without any experience were considerably less positive. Almqvist and Nygard (1997) found that 73% of drivers reported being more positive towards ISA after using it than before. Fifteen percent remained unchanged in their opinion and only 12% expressed more negative attitudes after experience of ISA. Similarly, Lahrmann, Madsen and Boroch (2001) reported that 15 out of 20 drivers became more favourable to using ISA after experience of the system. However the four who were negative prior to experience remained negative.

Overall, public opinion surveys and field trials certainly suggest that society has begun to recognise the harm caused by speeding. However, some drivers remain resistant to the concept and an overwhelming 62% of Tilburg drivers still evaluated driving with ISA less positively than driving without ISA.

### *2.3.2 Behavioural adaptations*

Traditional questionnaire based analysis provides the most detailed information regarding drivers opinions and resistance to ISA. However, changes in behaviour can also reflect and indeed influence the drivers acceptance of ISA. In general, trials of ISA systems have resulted in lower speeds. It is perhaps more interesting however that several other improvements and deteriorations in safety have also been observed. The primary concern has been to identify any negative behavioural adaptations associated with ISA. If drivers are resistant to the imposed control, their frustration may be exhibited in riskier driving behaviours. Indeed, drivers have displayed shorter headways on roads with higher speed limits (Várhelyi and Mäkinen, 2001) and exhibited riskier gap acceptance and delayed braking (Comte, 1996). Persson, Towliat, Almqvist, Risser and Magdeburg (1993) also noted that drivers tended to display increased speeds when approaching and driving in intersections compared to those who drove without an ISA system. However, Várhelyi and Mäkinen (2001) observed that approaches at roundabouts, intersections and curves became smoother in the speed range of 30-50km/h. Reduced speeds at entry to intersections were also observed in the large-scale Swedish trial (Biding and Lind, 2002). Indeed, whilst Persson et al (1993) report that drivers interacted with other drivers in an inappropriate manner more than those with driving without ISA, Almqvist and Nygard (1993) report the opposite and Várhelyi and Mäkinen (2001) note no difference. Several other improvements in safety have also been reported such as an observed reduction in the number of traffic conflicts (Persson, Towliat, Almqvist, Risser and Magdeburg, 1993; Almqvist and Nygard, 1997). In Tilburg drivers reported less overtaking and maintaining greater following distances. A UK study (Comte and Carsten, 1997) also found that drivers adopt longer headways and make fewer traffic light violations.

Although the data relating to negative adaptations is somewhat mixed, it can be seen that ISA certainly results in some safer driving behaviours. Bessling and van Boxtel (2001) argue that if the driver engages in more of this “conscious” behaviour, this would result in greater compliance to traffic rules and essentially reflect “acceptance of ISA in behavioural terms” (p.7).

Despite the positive evaluations of ISA, the questionnaire and behavioural based studies have highlighted some degree of resistance to ISA. It becomes important therefore to identify which individuals are least likely to adopt ISA and where people think it is appropriate.

### *2.3.3 Who?*

Very few studies have systematically examined individual differences related to the acceptance of ISA. In a comparison of participants and non participants of the Umeå trial, Garvill, Marell and Westin (2003) examined factors influencing drivers’ decision to install an ISA system. Groups differed with respect to age, perceived moral obligation to keep to speed limits, perceived correlation between speed and risk, perceived difficulty in keeping within the speed limits and number of reported speed violations. Lahrmann, Madsen and Boroch (2001) however found that risk awareness did not vary the *effect* of ISA as drivers still lowered their speeds. Indeed, whilst men were more likely to make speed violations, the extent of usual violations did not influence the effect of ISA as 6 out of 9 lowered their speed in the test. Nevertheless, these studies do suggest that psychological and demographic factors must be considered for acceptance.

Jamson (2002) examined differential use of a voluntary ISA system. Although a simulator study found no differences between drivers, an on-road study suggested that drivers who admitted to speeding were less likely to engage the system. Despite other influences upon system use such as traffic density and system penetration, the results do suggest that self selection bias could be a problem when implementing a voluntary system. Those who need the system the most are the least likely to use it.

It follows therefore, that voluntary implementation of ISA might also fail to target those who are most in need of the system. Implementation of an ISA system may have more potential if high risk groups are specifically targeted. Given that individuals tend to appreciate a concept as long as it is not imposed on them, introducing ISA primarily for these risk groups might provide a smoother pathway to the mandatory implementation of ISA for all drivers. Lahrmann, Madsen and Boroch (2001) found that 19 out 20 drivers believed ISA could be used as a measure for selected groups. Persistent speed offenders, novice and young drivers have been suggested by drivers as justifiable target groups for ISA (Biding and Lind, 2002). Company and commercial car drivers have also been identified as potential targets for ISA but Biding and Lind (2002) found that this cohort of drivers tended to express negative attitudes towards ISA and suggest that this should be “influenced by dialogue” (p. xi) between drivers and employers.

Given the differential use of ISA systems therefore, steps must be taken to ensure that any accompanied publicity campaign does not simply target the general population as a whole but rather that specific messages are tailored to those most likely to resist implementation.

#### *2.3.4 Where?*

In the light of the disapproval of speed camera and traffic calming measures from some parts of the driving population and the press, the autonomous architecture of ISA offers a desirable tool to curb speeds without the need to radically change the road infrastructure. Consequently the potential removal of some of the most aggressive of such measures with high penetration of ISA can be used to promote the benefits of ISA. Indeed, drivers within the Tilburg trial agreed that getting rid of traffic calming measures such as road humps was a favourable argument for the implementation of ISA (Bessling and van Boxtel, 2001). Almqvist and Nygard (1997) also found that drivers were more positive towards ISA than any other alternative speed reduction measures in urban traffic (except mini roundabouts) and Carsten and Fowkes (2000) stated preferences survey found that, in the UK, test drivers and the general public rated ISA as the most effective alternative remedy to greater enforcement.

The perception of ISA however can differ according road category thus it is important to determine where ISA is deemed most necessary. Drivers’ attitudes to current speed limits provide some indication of the likely resistance to ISA. Lahrmann, Madsen and Boroch (2001) suggested that almost all Danish test drivers would prefer speed limits to increase, particularly on highways and motorways. In the SARTRE 3 study, 43% of U.K drivers would prefer increased speed limits on motorways and 21% would prefer increases on main roads. However, when compared to the previous survey carried out in 1998 and 1994 fewer U.K drivers' state that the limit should be higher on main roads and more state the limit should be lower in urban areas.

In London too, 60% of respondents in a MORI (2005) survey supported the introduction of a 20mph speed limit on residential streets. Biding and Lind (2002) report that Swedish drivers agreed that 30 and 50km/h speed limits should be adhered to and Tilburg drivers believed that it was most important to keep to the speed limit on 50km/h, 70km/h and 90km/h roads and least important on the 110km/h roads. Unsurprisingly therefore, Biding and Lind's (2002) comparison across four Swedish cities found that 80% of drivers believed that ISA was most justifiable in 30km/h areas. On 50km/h roads in urban and residential areas and higher speed limit roads, the proportions drop. Almqvist and Nygard (1997) also noted that drivers were less positive about ISA's use in rural areas than urban areas. Differences here were explained because drivers had no experience of ISA on a rural road or expected speed to be regulated in urban areas. However this perhaps reflects a general resistance to ISA control on higher speed limited roads.

The results tend to suggest that acceptability of ISA is highest for slower urban and residential roads. This seems sensible given the increased number of potential hazards and the fewer opportunities to speed in these areas. However results from the Tilburg drivers experience provide contradictory results. Here, Bessling and van Boxtel (2001) report that the majority of drivers felt negative when limited to 18km/h. Although drivers did not perceive a difference in appreciation of ISA on 30km/h and 50km/h (in fact 60% found driving on these roads positive), appreciation was *highest* for the 80km/h roads. Nevertheless, whilst it is difficult to suggest which roads will cause drivers most frustration and thus hinder system use, it is fair to assume that emphasising the safety benefits of ISA in built up areas provides the most persuasive argument for those with no experience of ISA.

Developing a variable or dynamic ISA system that identifies certain locations and conditions in the network or weather, provides another potential benefit to increase public acceptance. Little research has examined drivers' experience of these systems but Várhelyi and Mäkinen (2001) reported that drivers do accept the need for an ISA system in certain critical situations such as slippery roads, at pavement defects, in poor visibility, in built up areas, at pedestrian crossings. Similar findings were also observed in the large scale Swedish trials where drivers considered ISA quite or very justified during the daytime in urban areas, in poor weather conditions and when road works were present. Várhelyi and Mäkinen (2001) suggest therefore that acceptance of these systems is optimal if ISA improves drivers' perceived safety. These system features also provide more emotionally laden arguments for implementing ISA (e.g. lowering speed limits outside schools) which may prove particularly influential with certain driver groups such as parents.

### *2.3.5 Willingness to pay*

The cost of ISA to the driver may prove a major obstacle to national roll out. Many ISA-related studies have therefore sought to determine how much drivers are willing to pay to have an ISA system installed. In an Australian study Mitsopoulos, Regan and Tierney (2001) reported that the majority of drivers were willing to have an advisory or mandatory system installed in their car if it were free. Almqvist and Nygard (1997) note that 58% of Swedish test drivers could imagine paying to have ISA installed but 42% would not pay. On average, drivers were willing to pay 900 crowns (£66.57 approx). Finnish drivers were willing to pay between 15-2500 euros (£10-1700 approx) (Päätalo, Peltola and Kallio, 2001). In the UK, Carsten and Fowkes (2000) reported that drivers were willing to pay £100 p.a. for local speed limiters and £148 p.a. for national speed limiters, whereas residents were willing to £15 p.a. for speed limiters (compared to £145 p.a. and £22 p.a. respectively for speed cameras everywhere). However, although Várhelyi and Mäkinen (2001) found that half of their test drivers would voluntarily install a speed limiter in their car, those who reported that they were more likely to speed in built-up areas more than other drivers, were significantly more likely not to install such a system. Again those who are in most need of the system demonstrate least acceptance.

Marchau, and Heijden and Molin's (1998) survey of the general public highlighted important issues surrounding drivers' willingness to voluntarily purchase an ISA system. Given that ISA could be introduced alongside lower taxes and/or insurance premiums, respondents were asked what acceptable net cost they would be willing to pay. The indications were that respondents were not willing to pay more than 150 euros (£102 approx) extra for ISA alone but when ISA was combined with additional functionality such as cruise control a slightly higher net cost was acceptable. Biding and Lind (2002) also highlighted that willingness to pay for a system was dependent upon the nature of the system. Fifty percent of drivers using an informative system were willing to pay to keep the system in their vehicle. However, this drops to 34% for those who had a warning system installed and between 29% and 40% for those with an active gas pedal installed. For those who were prepared to pay for their system the average sum was SEK 150 (£11.44 approx) a warning system, SEK 400 (£29.73 approx) for an informative system and SEK 500 (£37.16 approx) for the active gas pedal system. Considering responses noted earlier regarding the level of control of ISA, these studies would suggest that the attractiveness of ISA largely relates to its functionality in terms of the level of control it exerts on differing road types and the additional systems incorporated.

### *2.3.6 Implications for ISA marketing strategy in London*

Current literature has highlighted key recommendations for an ISA marketing strategy. The success of ISA in London will ultimately rely upon the attitude of the general public. In order to create a positive attitude it is imperative to convey the primary and secondary benefits of ISA. Indeed, both the Dutch and Swedish trial effectively used information and communication to promote their work. In the Netherlands, Bessling and van Boxtel (2001) reported that information and communication about ISA had a relatively large effect on attitudes and acceptance. A short intensive effort lifted the level of positive attitudes from 55% to 80%. The large-scale Swedish trials used a media strategy that kept a select number of journalists well-informed about the project, and conveyed as neutral message about ISA as possible in order for the general public to form their own opinions about the system. In addition, the project reports that demonstrations of ISA to key media contacts were vital to accurate media reporting.

A campaign should primarily emphasise the link between speeds and collisions and ISA's potential to reduce speeds and consequently deaths on our roads. However research has shown that individuals do not necessarily appreciate this link. Marchau, and Heijden and Molin (1998) investigated individuals' evaluation of ISA in terms of its overall safety benefits and the conditions under which they were willing to accept the concept. A set of 1489 households were contacted and 442 questionnaires were returned. When asked about the effects of ISA on policy goals and their relative importance, the results were somewhat at odds. Where ISA was expected to contribute to achieving a policy sub goal, the importance of this sub goal was rated as low and vice versa. Reducing traffic collisions and the propensity to speed were seen as the most important sub goals of ISA and fewer infrastructure barriers, more steady traffic flows and lower probabilities of penalties were rated as less important. However, only 58% of respondents strongly agreed that ISA would contribute to reducing collisions. Similarly, lowering the probability of penalties was not seen as a particularly important goal (31%) but 55% agreed that ISA was likely to contribute to this. It is important therefore that safety campaigns provide solid evidence that ISA can reduce collisions and the need to achieve such, in a manner that will instigate attitude change. Current research at the University of Leeds is examining key changes in psychological constructs following experience with a mandatory ISA system. This will provide important information regarding the psychological determinants of attitude change.

The London campaign should also highlight the secondary benefits of ISA. Research has shown that driving with an ISA system can improve drivers' attention to the road ahead and to vulnerable road users, impose a calming effect upon their driving style and visibly improve driver behaviour in terms of longer headways and fewer traffic conflicts. Whilst these effects are undoubtedly beneficial to the traffic network, individuals have also reported that they *feel* safer on the road. As Várhelyi and Mäkinen (2001) point out, acceptance of ISA is likely to be optimal if it improves drivers' perceived safety. It follows therefore that campaigns should suggest that ISA will make people feel better and safer. ISA can also improve congestion: with ISA speed variability is reduced so that traffic flow is smoother and the reduction in collisions will reduce incidents in the network.

Acceptance of ISA however has been shown to differ across individuals. The literature suggested that those who are most likely to speed are in fact those most likely to express resistance to the system and least likely to voluntarily use a system. Little research has examined individual differences and more is certainly required. A crude indication would be to identify those groups of individuals who frequently engage in speeding. (e.g. young males) but the processes involved in predicting acceptance and system use are undoubtedly more complicated than this. Nevertheless, surveys have identified key target groups for ISA (e.g. novice and young drivers, speeders, commercial drivers) deemed appropriate by the public.

The trade-off between reduced traffic calming measures such as roads humps and ISA was discussed as a potential bargaining tool for the introduction to ISA. Although frustration differed across roads types, research from ISA countries overwhelmingly suggested that the general public felt ISA was most justifiable for lower speed roads in residential and urban areas. Since a small reduction in speed on these roads could mean the difference between life and death, targeting the potential of ISA in these areas provides a persuasive, emotionally laden message.

As Biding and Lind (2002) surmise, if willingness to pay for an ISA system is low, it is important to promote ISA through subsidies and reduced insurance. The Netherlands are currently investigating the effect of rewarding drivers in order to change behaviour and attitudes in the Belonitor trial. Drivers will be rewarded with points that can be exchanged for events/days out (relaxation, culture, sports, inside or outside events) for maintaining a sufficient distance form the car ahead and keeping within the speed limit. Results will indicate whether drivers' behaviour can be influenced through rewards and thus traffic safety improved.

Marchau, and Heijden and Molin (1998) identified that individuals' willingness to pay for ISA was also related to its functionality in terms of the level of control it exerts on differing road types and the additional systems incorporated. Since drivers are more motivated to buy a system for other features such as cruise control, it may be worthwhile combining ISA so that drivers can choose whether to use this feature. Evidence has suggested that experience increases acceptance of ISA, thus a multi functional platform could provide an ideal opportunity for drivers to try this technology. Similarly, whilst a mandatory system offers the greatest potential, acceptance of this level of control is likely to be weaker.

An ISA system could therefore offer different functional variations (Biding and Lind, 2002). However, developing this level of functionality for a prototype system would prove difficult and a feature such as cruise control is unnecessary in London (due to low driving speeds). Nevertheless, the results emphasise that the functionality of ISA is critical to acceptance and more appropriate features such as navigation system could be incorporated. Indeed, a stakeholder survey conducted across eight European countries (Beyst, 2004) concluded that this type of system would gain the highest political and public acceptance. Various implementation scenarios were compared and introducing a warning or intervening ISA as part of a telematics platform (without incentives) which offered other features such as route guidance and navigation, lane departure warning and traffic information service, downloaded from a central server in a traffic management centre, was deemed the most *acceptable* implementation path. Alternatively, the most *effective* scenario for improving safety, the environment and congestion involved an advisory system fitted to all drivers' cars where the speed limit changed according to traffic conditions (congestion, collision), weather (heavy rain, darkness, snow, ice, fog) and spatial characteristics (residential areas, schools, junctions, dangerous curves). Although this was the most preferred implementation path for all countries, the UK expressed a considerably weaker preference than their counterparts. Moreover, UK stakeholders (commercial companies, pressure groups, researchers and government bodies) were rather negative towards the contribution of ISA to traffic safety, congestion and the environment suggesting that, in this country, it is perhaps more effective to emphasise the material rather than social benefits of ISA.

Beyst (2004) surmises that the most significant barriers to the implementation of ISA are the technical functionality of the system, the applicability to the road network and the benefit to the customers. Essentially, public confidence and support must be optimal before ISA is enforced and perhaps more importantly the system needs to be reliable leaving no or little room for criticism. On a wider scale, European directives and legislation concerning the liability of the system need to be developed and harmonisation of standards achieved. At the moment such harmonisation is embryonic, although the recently completed Speed Alert European project has examined some of the necessary steps.[2]

[2] The reports from Speed Alert are not yet available.

## 2.4 Legal framework and policy issues

### 2.4.1 Regulations

There is, as yet, no current required procedure for the approval or certification of Driver Assistance Systems such as ISA. Vehicles such as passenger cars are subject to a legally required approval process, in particular the EC Whole Vehicle Type-Approval system, which became operational in 1993 under Directive 92/53/EEC,

Another set of regulations are generated by the UN-ECE in Geneva. These ECE approvals are system or component type approvals and do not cover the whole vehicle. ECE automotive regulations currently cover a wide range of technical requirements for motor vehicles, including (in an area relevant to ISA) braking systems. It is considered an offence, under the Road Vehicle Construction and Use Regulations, to modify such ECE approved systems as braking systems. This could apply to an ISA system which applied braking to slow a vehicle down by means of a system or sub-system that interfered with a vehicle's braking system. For this reason, the braking applied to the vehicles used in the External Vehicle Speed Control and ISA-UK projects has been by external means, i.e. a system that pulled or pushed the brake pedal down.

A further set of regulations deal with modifications to the vehicle *after* manufacture. In the UK, the applicable regulations are the Road Vehicle Construction and Use Regulations. Among other areas, these cover Electromagnetic Compatibility (EMC). A criminal offence is committed by the user of the vehicle or of vehicle parts, and by the fitter and supplier, if components do not comply with the relevant regulation (sections 42 and 76 of the Road Traffic Act 1988). Under these regulations, Electronic Sub-Assemblies (ESAs) intended for fitment in passenger cars are required to be "e-marked" to show compliance with the regulations. Typical examples of an ESA are in-car entertainment equipment such as radios or CD players, accessories such as mobile phone car-chargers and spare parts such as ABS modules. Examples of equipment which falls within the regulations are:

> "a) Equipment which was not intended for fitment to a vehicle by the manufacturer, but nevertheless which is being installed in a vehicle or vehicles, by an organisation on a commercial basis. For example, a company installing computers in vehicles as a permanent fixture.
> b) Equipment that is marketed on the basis that it is suitable for installation in a vehicle. For example, a "travel laptop" advertised as suitable for use in a car and perhaps provided with an adaptor to enable use of 12v supply."

Thus ISA systems (even for purely advisory ISA, provided that it draws power from the vehicle) would appear to come into the category of an ESA. Testing of ESAs for compliance is normally carried out by a test house authorised by the Vehicle Certification Agency.

### 2.4.2 Recommended safety assessment

The duty to ensure that an ISA system is properly designed and is safe in use does not end with conformity to the legal construction regulations. There is clearly a potential legal liability from poor design of either hardware or software (or the interaction of the two). It is therefore incumbent on the designer of a system, and in particular of any kind of ISA that will intervene in vehicle control, to ensure that best practice has been followed in the design of the system. Thus, in the ISA-UK project, a Preliminary Safety Analysis (PSA) and Safety Case was carried out on the proposed system quite early in the design cycle.

The objective of a PSA is to classify all the safety hazards that can be identified from the current description of the system. Hazards are defined as "a physical situation with a potential for human injury" (IEC 61508), and they can be found by performing a "What If?" analysis on a theoretical model of the system. Each hazard should then be assigned a Controllability Category to indicate the degree of risk associated with it (MISRA, 1994) and appropriate actions taken to eliminate or minimise the risk of a hazard occurring, particularly for those hazards which are assigned to high (more dangerous) controllability categories.

It is therefore necessary to produce a "model" of the system so that the possible interactions between it and its environment (i.e. everything that might affect, or be affected by, the system) can be readily identified. A standard way to produce such a model, which has been specifically developed for transport telematics systems such as Driver Assistance Systems, is to create a PASSPORT Diagram (Hobley et al., 1995).

This procedure was applied to the design of the ISA system for the ISA-UK cars. A number of "What If?" scenarios and resulting hazards were identified and subsequent steps taken to ensure that the risks of serious hazards occurring was minimised. The most drastic solution was the adoption of a "safety bag" or envelope surrounding the ISA system with the following properties:

a) The throttle signals passed to the Engine Management System shall never be greater than those implied by the driver's depression of the throttle pedal.

b) There shall be a physical "stop" on the brake actuator to limit the amount of automatic braking that may be applied.

An analogous procedure would have to be applied in the design of any new intervening ISA system. Equally it is important to carry out rigorous testing of ISA prototype vehicles to ensure their reliability. Every effort should also be made to reduce the possibility of a vehicle receiving wrong speed limit information as a result of either errors in the speed limit database or of location error (the vehicle concluding that it is in a different location from actual location). Here the vehicle inferring a lower speed limit than that actually prevailing is probably a greater hazard than it inferring a higher speed limit.

# 3. TECHNOLOGY REVIEW

ISA systems that have been developed are reviewed in Appendix 2. This section provides an overview of the component parts of a potential ISA system.

The technology to deliver ISA has three elements:

## 3.1 Position

The vehicle needs to know where it is. There are two solutions to this. One way is by means of electronic signals transmitted to the vehicle from **roadside beacons** attached to speed signs or other roadside infrastructure, such as lampposts. These beacons transmit information regarding the posted speed limit to the vehicle and an on-board computer triggers the warning and/or limiting system if the vehicle exceeds this limit. The Swedish (Umeå) trial adopted this approach, using in-vehicle equipment consisting of a RF receiver, a microprocessor, electronic compass for direction, a pulse-counter for distance measurement and an in-vehicle display. The advantage of the beacon system is that it is immediately operational as the vehicle passes it, with little delay. The disadvantages relate to maintenance and initial set-up costs. The Swedish system cost approximately £100 for the initial installation of the beacon, not counting the on-going maintenance. Furthermore, there is the possibility that road network information may fail to download into passing vehicles, which means that these vehicles would be travelling at an incorrect speed until they pass the next beacon (Carsten & Tate, 2001). In the Umeå trial there were also problems experienced with the electronic compass due to magnetism.

Ideally, the vehicle should know on which road it is being driven, where on that road it is currently located and in which direction along that road it is travelling. An alternative approach, and the one that is being adopted most widely in ISA trials around the world, utilises **global positioning system** (GPS) technology combined with map-matching and dead reckoning techniques. The accuracy of an uncorrected GPS receiver ranges from 5 to 15 metres. A differential Global Positioning System (dGPS) is also often used and improves the accuracy of the position determination to within a metre. The dGPS receiver is a special FM radio receiver and usually requires a subscription with a service provider. A GPS-based navigation system can supplement information acquired from the GPS with dead reckoning (from compass and yaw sensor) and map-matching. The new European correction system, GNSS, will provide additional accuracy, as will the new satellite system, Galileo, when it becomes operational.

***Implications for a London trial***

A telephone survey of the London Boroughs was undertaken to establish roughly how many speed limit changes occurred in each and in what format the data were stored. The results can be seen in Appendix 3. Twenty-six of the boroughs hold information on the speed limits in paper format in a point to point format. Such points could be, for example, house or lampposts numbers. This provides an accurate guide as to where to position the virtual beacons on the digital road map, with the appropriate speed limit attached. Of those 26 Boroughs, 14 hold this information in an electronic format, reducing the cost of actually sourcing the information.

With regards to the number of speed limit changes, this varied widely. Twenty Boroughs were able to provide an approximation, and these totalled to 365. With 33 Boroughs to consider, and given the fact that some figures are known to be underestimations, the Greater London Boroughs would appear to be responsible for approximately 600 speed limit changes. The London Boroughs also include roads under the jurisdiction of The Highways Agency/TfL. Seventeen Boroughs were able to provide information regarding these, totalling to 70 roads. Again a rough approximation could double this to account for all boroughs.

## 3.2 Information

For a beacon system to operate, a central control system needs to exist, which defines the attributes for each beacon and downloads this information into each beacon using a mobile communication. This allows for speed limits to be changed, e.g. in the event of roadworks.

With a GPS set-up, there needs to be a digital road map on board the vehicle which contains the speed limit for each stretch of road. This should ideally be in the form of an attribute of the road, so that as soon as the navigation component realises that the vehicle is travelling on a particular stretch of road, the ISA system will know the speed limit. This digital road map could be stored on a device such as a CD-ROM, but this makes updating cumbersome with manual intervention (and vehicle owner cooperation) required. In the future the entire local map, including the speed limit information, could be downloaded into the vehicle over a digital radio network, thereby ensuring that the information was up-to-date and also providing a dynamic capability to change speed limits in accordance with current conditions. Currently however, there is no such provision and the digital road map, with speed limit positions, would have to be created “by hand”. Changing the speed limits then becomes relatively quick and easy, providing these changes can be transmitted automatically to the vehicle over a digital radio network such as the third generation mobile phone system (3G). The limitations on the GPS technology include loss of signal in built-up areas and confusion where roads with differing speed limits cross. Using a navigation system beneath the ISA helps in addressing these problems. In addition, newer GPS systems are less prone to drop-out from “urban canyons” and the enhancement of GPS with GNSS and Galileo is predicted to virtually eliminate such drop-outs.

Sweden and Finland will have national digital road maps, incorporating speed limits, this year and Norway already has one. The UK Department for Transport is considering whether to promote such a map, following the recommendation of the Transport Committee of the House of Commons that the government should fund the development of such a map (House of Commons, 2002). DfT has awarded a consultancy contract to investigate map issues.

***Implications for deployment in London***

How will the digital road map be configured and provided? What size of map is feasible in terms of data storage? The team are aware of problems in the Ghent ISA trial, whereby the maximum (in-car) map size was exceeded. Map providers, such as Tele Atlas and Navteq, should be contacted in the initial stages of further planning to provide advice on this issue.

## 3.3 Control

For an “Intervening” ISA, there needs to be a link from information to the drivetrain. Clearly, for an informative or warning ISA, the elements of positioning and information are sufficient, and they could be packaged in a small unit, for example a PDA. But for an intervening system, there needs to be a link to vehicle throttle control and perhaps in addition (in order to prevent substantial exceeding of set speed) to the braking system. It should be noted that the level of control over the vehicle can vary from “soft” in which driver inclination to speed is resisted to “hard” in which speeding above a certain point is prevented unless an override is provided. The level at which the system cuts in can be set by the system designers so that a certain margin of speeding can be allowed before system intervention. Inappropriate harshness of intervention at a speed limit change can be prevented.

A number of vehicles on the European market have the option of a driver set manual speed limiter. This function is normally an additional one to Cruise Control functionality. One such vehicle is the Renault Laguna II. It may be considered that such a function could offer the basis for a ISA system if the driver set speed switch could be interfaced to data from a speed limit information aspect used within current ISA work. It should be noted that the French project LAVIA is using both Peugeot 307 and Laguna II models and may be utilising an interface to the driver-set functionality.

The level of control exerted will have implications for the method of applying ISA to host vehicles, the type of vehicle and the cost implications. These are explored in Section 5.

# 4. SAFETY BENFITS OF ISA

This chapter provides a brief overview of the collision savings that can be obtained with ISA. This topic is addressed both from a network perspective (i.e. how many collisions will be saved in a road network if all vehicles are equipped with ISA) and from a fleet perspective (i.e. how many collisions will be saved in a fleet of 100 cars equipped with ISA). Additional benefits, such as travel time savings are not covered here.[3]

## 4.1 Network collision savings

The most detailed prediction of overall network savings with ISA is provided by Carsten and Tate (2005). Table 1 shows the estimates of the overall system-wide collisions savings for Great Britain, at various levels of collision severity, for various permutations of ISA The scenario envisaged is that 100% of vehicles are equipped with ISA overnight. ISA systems are divided into the broad classes of Advisory, Driver Select, and Mandatory systems. Advisory ISA displays the speed limit and reminds the driver of changes in the speed limit. Voluntary ISA is linked to the vehicle controls but allows the driver to enable and disable control by the vehicle of maximum speed. With Mandatory ISA, the vehicle is limited at all times. Each broad class of ISA can have speed limits in fixed, variable or dynamic forms (where dynamic also includes variable capability). With “Fixed” speed limit data, the vehicle is informed of the posted speed limits. With “Variable” data, 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, so that with a Variable system, the speed limits are current spatially. With “Dynamic” data, additional lower speed limits are implemented because of network or weather conditions, to slow traffic in fog, on slippery roads, around major incidents, etc. Thus with a Dynamic system, speed limits are current in terms of time.

From Table 1 it can be seen that implementing Mandatory Fixed ISA (equivalent to getting all vehicles to obey the current posted speed limits) produces a 20% reduction in injury accidents and a 37% reduction in fatal accidents. Implementing Mandatory Dynamic ISA is predicted to save 36% of injury accidents and 59% of fatal accidents.

[3] In any case, the reduction in travel time implies that the initial benefits were gained illegally (through speeding). An initial analysis by TfL suggests that any journey time increases would be small. Indeed, journey time could improve due to reduced speed variation.

**Table 1: Best Estimates of Collision 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% |
| Voluntary | 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% |

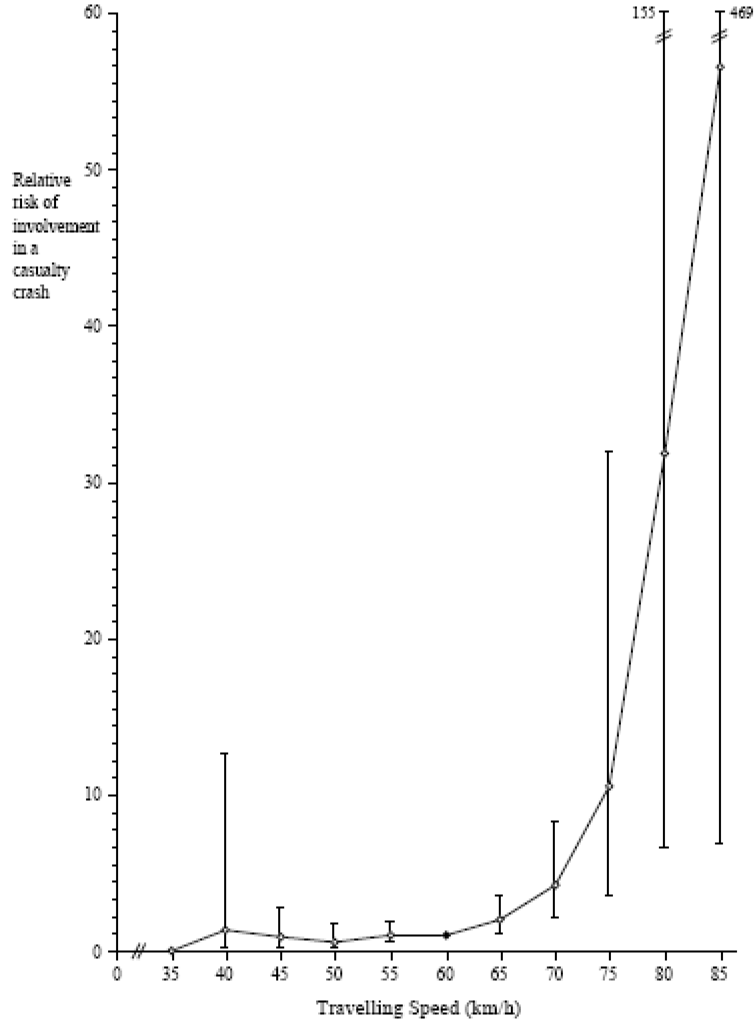
(source: Carsten and Tate, 2005)

Given the different road mix in London as opposed to nationwide, the predicted benefits for London might well differ from those for Great Britain as a whole. But the numbers above do provide an indication of the very large safety potential of ISA.

## 4.2 Fleet collision savings

The safety benefit of ISA to a fleet, will not necessarily be the same as the safety benefit in a network. In particular, when small numbers of vehicles are equipped with ISA, most other vehicles with which they interact will continue to be non-ISA. So it is necessary to use a different methodology — one based on individual vehicle changes in risk when speed limit compliance is increased, rather than a methodology using known relationships between speed and collisions for lengths of road.

An Australian study has investigated the relationship between speed compliance on urban roads and the risk of a vehicle being involved in a crash (Kloeden, McLean, Moore and Ponte, 1997). The study a case-control methodology, in which case vehicles were vehicles involved in crashes (speed before crashing was calculated by collision reconstruction) and control vehicles were matched vehicles observed in the traffic stream. The study was carried out on roads with a speed limit of 60 km/h. The resulting prediction of risk by travelling speed is shown in Figure 1.




Note: Relative risk at 60 km/h set at 1.00.
95 per cent confidence intervals are shown by the vertical lines.

**Figure 1: Travelling speed and the risk of involvement in a serious casualty crash relative to travelling at 60 km/h in a 60 km/h speed limit zone**
(source: Kloeden et al., 1997)

The case vehicles selected in this study were vehicles involved in crashes where at least one person was transported to hospital by ambulance. Therefore the risks in Figure 1 are in UK terms for involvement in *serious or fatal* crashes. It can also be noted that the study was carried out on 60 km/h roads (prevalent in Adelaide) as opposed to the 50 km/h roads prevalent in London. But it is reasonable to assume that the same risk curve applies on 30 mph (50 km/h) roads and adjust the X axis points so that the relative risk at 30 mph is 1, etc.

This risk curve can then be combined with the observed changes in speeds on 30 mph roads for the drivers who have participated in trial 1 of the ISA-UK project. This trial has used a voluntary intervening ISA of the type that might be deployed in London. The result is a predicted reduction in serious and fatal crashes of 27.5%. By applying the formulae from Andersson and Nilsson (1997) which relate changes in mean speed to changes in collision risk at various levels of severity, it is possible to translate that reduction in serious and fatal crashes into a predicted reduction in injury accidents in an ISA-equipped fleet. That predicted reduction is 19.3%. As with any safety prediction, the numbers are indicative. They are the best estimate currently available, but of course traffic conditions in London may differ from those in Leeds (although both are highly congested networks) and the Leeds drivers in the trial may differ in their behaviour from London drivers. There is thus an argument for further modelling to be undertaken using data sourced from London's roads.

## 5. PROVISION OF ISA FOR LONDON

In order to provide ISA for vehicles in London a number of requirements and functions have to be provided. They are:

1. Preparation of a reliable digital road map incorporating accurate *information* on the location of changes in speed limit
2. Technology for the vehicle to realise their *position*
3. On-board *processing* to combine (2) with (1) and thereby provide speed limit
4. An in-vehicle Human Machine Interface
5. For an intervening ISA, a means of linking this processing to *control* (or feedback in the case of a haptic throttle)
6. For a recording ISA, a mechanism for *recording*. Recordings could be made of system overrides for an intervening ISA or of distance travelled in excess of the speed limit for an informative ISA.
7. The incorporation of a capability for automatic *updating* of the in-vehicle map over a digital radio link, such as a mobile phone link.

This schematic architecture is illustrated in Figure 2, with optional items and links in blue.

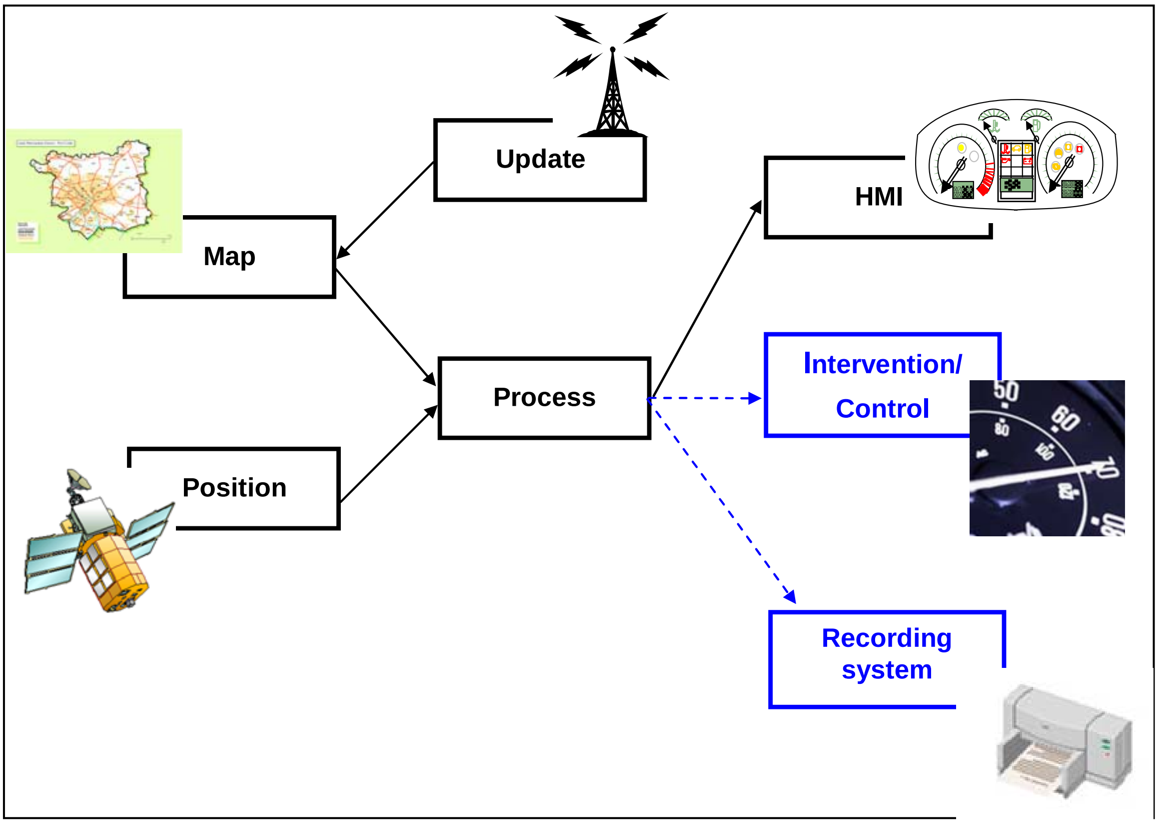



**Figure 2: Schematic architecture of an ISA system**

## 5.1 Information: the digital map

It is highly likely that an adequate digital road map with speed limit information already exists for Greater London. Under contract with TfL, Ordnance Survey (OS) have already mapped speed signs within the M25. The speed signs have been incorporated as nodes within the new OS Integrated Transport Network database. According to OS, this information has been checked through a quality assurance process.

Clearly this OS map needs to be further verified, before it is used in an ISA deployment. TfL might also need to decide whether the “true” location of a change in speed limit was the sign location or the location defined in the speed limit order (the legal instrument for implementing a change in speed limit). In Leeds, the location specified in the orders were used. It would also be necessary to ensure that the map is kept up to date with all changes in speed limit implemented by the boroughs, by TfL and by the Highways Agency. The opening of new roads also needs to be considered.

If it is in the end decided that the OS map is not an adequate source, then it would be necessary to build an equivalent map from scratch. We have been able to estimate roughly the number of speed limit changes (i.e. signs) within the Greater London area. However, without knowing the intricacy of the speed limit changes, it is impossible to estimate accurately how long it would take to implement a map. For example if a 20 mph zone can be defined cleanly with clear boundaries, this is relatively simple to implement. But, if the 20 mph zone has a number of exclusion zones where the speed limit reverts back to 30 mph, this takes longer to map.

In Leeds, a half-person year was required to map an area of approximately 560 square km and a total road length of 2600 km. This mapping was carried out with the cooperation of the highway authority, Leeds City Council, and using a considerable amount of local knowledge. Speed limit orders were used as the information source for locating changes in speed limit, as they provide the information with the required degree of accuracy. The information acquired was also checked on street.

Subsequent experience in the ISA-UK project with creating the second local map, (for rural Leicestershire), has confirmed that the approach of using speed limit orders is the right one. Leicestershire County Council offered their own digitised map as the information source on speed limit changes, but in actual use the ISA map created using this source has turned out not to be of sufficient accuracy, resulting in complaints from the drivers. The main problem is that on the approaches to villages, changes in speed limit are recorded on the Leicestershire map as occurring at the nearest junction, i.e. links are defined as having a single speed limit. This is not always the case in reality: speed limit changes may occur in the middle of a link and this needs to be considered in an ISA map by breaking that link into sublinks at the point of change. This breaking of links where needed was done for the Leeds map.

We envisage Greater London to be much more time-consuming than Leeds to map, for a number of reasons:

- It is a larger area

- The data is not held in a central location
- The bigger the area, the harder it is to apply local knowledge

With Greater London covering 1580 square km, the task has immediately trebled, and so the lowest estimate becomes 18 person months. Another dissimilarity with the Leeds map, is the length of the road network (see Table 2). The total road length in Greater London is almost 5 times that of Leeds, giving a higher estimate of 2.5 person years.

**Table 2: Road lengths by type, in Leeds and Greater London**

| **Road type** | **Road lengths** | | | |
|---|---|---|---|---|
| | *Leeds* | | *Greater London* | |
| | **Km** | **%** | **Km** | **%** |
| Motorway | 68 | 2% | 60 | 0.5% |
| Dual Trunk | 13 | 0.5% | 0 | 0% |
| Single Trunk | 46 | 1.5% | 0 | 0% |
| A Dual | 61 | 2% | 434 | 3% |
| A Single | 177 | 6% | 1281 | 9% |
| B | 71 | 2% | 514 | 3.5% |
| C | 150 | 5% | 873 | 6% |
| Unclassified | 2454 | 81% | 11546 | 78% |
| **Total** | **3040** | | **14708** | |

With the data not being held centrally, but with the individual boroughs, it will take some time and cost to initially collate this information. Another important issue to consider is how the map will be updated. This applies not only to changes in the speed limits, but also to the building of new roads.

The map should also include information for the national trunk road network, so that drivers will have ISA available on trunk roads and motorways. This information is already provided in the commercial digital maps from providers such as Navteq.

Once the *source* map has been built and verified, it will be necessary to translate that map into an *on-board* map of the type used in the current ISA-UK trials. In the current national project, that translation as carried out by Navteq, via a subcontract. The cost for such a translation will have to be incorporated in the costs of any London deployment.

## 5.2 Updating the in-vehicle map

One of the problem areas for ISA deployment is how to keep the on-board digital map up-to-date. New digital communications systems such third-generation (3G) mobile phone should now provide enough bandwidth to make it practical to download updates to the map into ISA-equipped vehicles. This approach is now becoming more common in the newer ISA projects such as the one recently started in Denmark, which is planning to use GPRS (2.5G mobile phone) for this purpose. Such a functionality is recommended for ISA deployment in London. It would mean that the in-vehicle maps were automatically kept up to date and avoid any need for costly and inconvenient manual updating. The would be some consequent costs in terms of the phone charge for sending the data, but this would be more than outweighed by the costs saved by not using manual updating. No problems of network overload from data transmission are foreseen.

## 5.3 Intervention level of an ISA system

Lastly but by no means least, careful consideration needs to be given to the level of ISA chosen for London. Advisory-only systems would be much simpler to deploy, since they do not necessarily require any interface to the vehicle beyond mounting. However, advisory ISA will be substantially less effective than an intervening system in terms of speed reduction and safety impact. One overall estimate is that an advisory ISA will have 40% of the safety impact of a mandatory (non-overridable) system (Carsten and Tate, 2005). However this estimate is based on data drawn from subjects in trials who knew they were being observed. In real-life deployment the compliance is likely to be significantly lower.[4] Of course initial uptake of an advisory system might be greater and fitting would be much simpler (an add-on, nomad system would be feasible), but there would be little assurance of substantial safety benefits.

Therefore three alternative systems would be much more effective. The first would be an advisory system for the general market, which simply provided the driver with the posted speed limit. The second would be an enhanced advisory system which incorporated a recording functionality. This ISA would record infractions of the speed limit for subsequent use in feedback to the drivers. Compliance could be rewarded and/or violations punished, for example by financial rewards and penalties. This could initially be aimed at fleets to manage operation road risk. In a fleet situation it might not even be necessary to use any other incentive to comply beyond written and verbal feedback.

The third alternative to be considered is an intervening ISA with opt-out functionality of the type being used in the current ISA-UK trials. Once again compliance, i.e. not using the opt-out or override, could be encouraged with appropriate incentives and disincentives. This could be used in the trial fleet and the TfL vehicles, potentially including buses and taxis.

[4] No controlled direct comparisons of ISA advisory and intervening systems have been carried, so exact estimates of the reduced effectiveness of an advisory ISA are not possible.

# 6. DEPLOYMENT OF ISA IN LONDON

## 6.1 Alternative approaches

If TfL wishes to promote the deployment of ISA in London as a means of achieving both its current road safety targets and to achieve any future targets beyond 2010, then a number of approaches can be adopted, perhaps in parallel. There are three different “markets” for ISA:

1. Vehicles for which TfL is the regulatory authority, namely buses and taxis
2. TfL’s own fleet of cars for use by employees and officials and vehicles used by organisations closely related to TfL, such as the Greater London Authority (TfL’s parent organisation) and the Association of London Government (ALG)
3. Private motorists

Each of these alternatives is discussed below in terms of technology requirements, likely casualty reduction and incentives required for adoption. The same information source, i.e. digital road map with speed limits, could be used for each of these alternatives.[5]

## 6.2 Buses and taxis

There are some 8000 buses in London, of which the older models such as the Routemasters which have been withdrawn from use. As discussed in section C, the current ISA-UK project is fitting an HGV with ISA. The plan for the HGV is to use an off-the-shelf throttle pedal intervention, the Pedal Interface II, manufactured by Siemens VDO to provide the ISA control. This approach would appear to be ideal for the London bus fleet. It would almost certainly be more acceptable to drivers than the rather public feedback from a warning ISA. Clearly a detailed review would have to be conducted of the mix of vehicles in the London bus fleet, of the feasibility of any proposed technical system for each bus model and of any special fitment issue, e.g. installation space, for each bus model.

As regards London taxis, there are some 20,000 vehicles licensed by TfL’s Public Carriage Office. There are only two manufacturers of these vehicles, LTI (London Taxi International) and Metrocab, thus simplifying design and installation aspects of ISA modification. There are in addition around 40,000 private hire vehicles in London, but fitting them would be much more arduous in view of the lack of uniformity in the vehicle fleet.

Using the numbers from section 4.2, it is possible to calculate the predicted annual savings in casualties were taxis to be equipped with an intervening ISA. In 2004, licensed taxis were involved in a total 662 injury accidents in London. A reduction of 19.3% in those collision involvements would mean that the total would be reduced by 127 involvements. This is, of course a tentative calculation and would need to be further investigated to include actual speed data from London’s taxi fleet.

In 2004 there were 2933 injury accidents in London in which at least one bus or coach was involved. Applying that same 19.3% reduction would mean a saving of

[5] In practice, a map covering all streets in London would not be required for a bus-only application — only bus routes would need to be covered. There might therefore be some cost savings associated with creating a map for buses only.

566 injury accident involvements, but that number is an overestimate of the impact of fitting London buses since (long-distance) coaches are also included in these accident figures. It is not unreasonable to suppose that 400–500 involvements for buses could be saved. However, as for the taxis, this would need to be verified with further work using data gleaned directly from London.

## 6.3 TfL's fleet and vehicles of related organisations

### *6.3.1 General approach*

A number of vehicles would be purchased to create a fleet of ISA cars to be used by appropriate drivers. Some of these drivers might be long-term users; others might be short-term drivers using "pool" cars.

### *6.3.2 Vehicles*

The type of vehicle to be selected will be likely to be a mid-sized family car that also provides an appropriate platform for the ready installation of ISA related hardware and associated electronics. Fleet size would depend on budget. A larger fleet would cost more, but per-vehicle cost would be reduced because the design costs would be spread over a larger number of vehicles and because of likely savings in purchasing from buying components in greater numbers. The cost of the vehicles themselves is not relevant as vehicles would have to be procured whether or not ISA is implemented. The experience of ISA-UK and other trials has indicated that no substantial driver training is required, since ISA is essentially intuitive.

A possible candidate based upon currently available models is the Toyota Prius 2 which is illustrated below in Figure 3. The Prius 2 is a hybrid vehicle which utilises both internal combustion and electrical engines to provide pollution and fuel economy benefits. It therefore may be considered a greener alternative to many other current vehicles. TfL already own a number of Prius cars for use as pool vehicles.

**Figure 3: Toyota Prius 2**

It is likely that within the near future there may be alternative hybrid vehicles which may also be considered. In the general context of ISA compatibility it may also be noted that Hybrid vehicles use regenerative braking when the throttle demand is decreased. This uses a powertrain mounted generator to drive current back into the vehicle batteries. It also has the effect of actively slowing the vehicle when the driver lifts off the accelerator. This is beneficial in an ISA context as there may be therefore no need to consider any additional braking activation to bring down speed such as that used in the ISA-UK vehicles.

### *6.3.3 ISA functionality*

To ensure the highest compliance rates, a voluntary system will be implemented. Drivers will have ISA available to them at all times, although there will be an override function for safety purposes. There will be no kick-down function, as the UK trials have found that drivers did not use this as an override option (they preferred the steering wheel buttons).

### *6.3.4 Hardware*

Either a PDA or an embedded PC could be used. There are no substantial cost differences between these two approaches, but a PDA provides more flexibility with regards to its physical location and is likely to have fewer battery problems. PDAs were used in the Swedish ISA trials, see Figure 4.


**Figure 4: PDA used in the Swedish trials**

### *6.3.5 Incentives*

Whilst the ISA system proposed is an opt-out intervening one, the current Leeds trials show that opting out is undertaken at a rate of approximately 10% of distance travelled (depending on the road type). Whilst this might appear to translate into a good compliance rate, it should be remembered that these drivers were monitored closely and were bound by a contract. This in effect provided an incentive for them to comply. Close monitoring of a large fleet is possible using enforcement techniques, and effectively acts as an incentive as in the case of the Finnish taxi trials (punishing negative behaviour). However, positive incentives could also be used, although they have not been tested so far in any ISA trials. Monitoring implies using at least some kind of recording system, at least to identify when and where the system has been overridden and what the maximum speed was after the override.

We suggest that a cut-down version of the data collection currently used in the UK trial is implemented. This will not only reduce the cost per vehicle but increase the flexibility available for the transmission of the data. The data could include, for example:

- 1 speed measurement per second
- Usage rates (ISA state)
- Where ISA is turned off (speed limit/geographical location)

Ideally, data collection should not impose on the drivers and should be as hands-off as possible. This will reduce any feelings of being "spied upon" but also make the trial seamless in that members of the technical team would not have to visit the cars for the purposes of data download. This data transmission could be achieved using 3G mobile networks. The same data link could also be used for the transmission of the map updates, thus creating a two-way communication link. The data received would be stored on a secure server, similar to the set-up currently used in Leeds.

#### *6.3.6 Timescale*

The timescale presented is only a rough indication; much will depend on the final system solution and the vehicles used. We suggest that the programme of work is broken down into five main phases:

**Phase 1 Months 0-9**
The initial design and specification of the desired ISA system and the building of a test vehicle.

**Phase 2 Months 10 - 15**
The fitting of the approved system to three further vehicles and appropriate road testing. Depending on the design, DfT approval (or at least notification to DfT) might be required.

**Phase 3 Months 16 - 19**
Decision points and tendering process for the conversion of the large fleet

**Phase 4 Months 20 – 26 (?)**
Installation of ISA in a fleet of perhaps 50 vehicles

**Phase 5 Months 24 - onwards**
Identification of drivers, acquainting drivers with the ISA functionality (no specific training is envisaged), running the trial and fleet maintenance

Phase 1 will design and develop a full ISA specification, shown in **green** on the timeline. This initial phase will also include time to consider overall detailed logistics and where contractual arrangements are set-up. For example, contacting Toyota to see if they would participate in any way, contacting a GPS/map provider, talking to leasing companies about the various options and the purchasing of the first mule vehicle.

Phase 2, shown in **purple**, will build and install the ISA system in a mule vehicle. Following system approval, including EMC and track trials, some on-road piloting will

be carried out. On successful conclusion of this, a system specification would be agreed based on the functionality desired and achieved. That is then implemented on a further three vehicles and subsequently road trialled for two months to investigate durability, reliability and geographical/GPS/map issues.
This timeline assumes there are no delays, no incidental delays/suppliers etc, and no significant obstacles. At the end of this phase, 4 vehicles will have trialled the system, providing around 50K miles of experience exhaustively. The advantage of this procedure, is that following the second system approval procedure, there will exist a “finalised” design. This could then be theoretically to a third party(s) for the large fleet conversion.

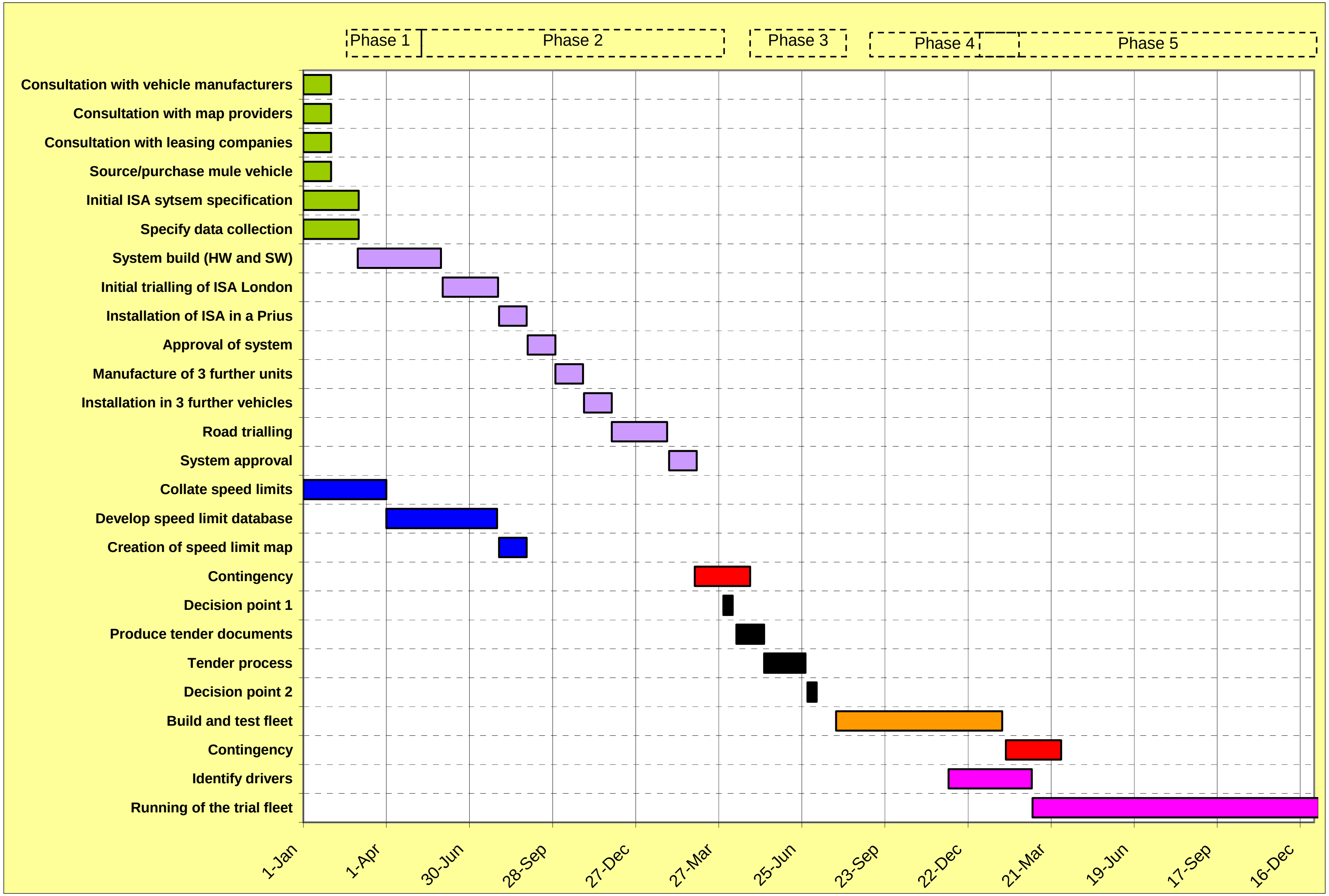
The speed limit map for Greater London will be developed in parallel, as shown in **blue**. Initial testing of the first prototype vehicle can be carried out using a dummy map. However the additional three vehicles will require the actual map (ideally we would have the map before the project gets underway). How quickly the speed limit map can be mapped will depend on the ease of obtaining the information from the Local Authorities, and the number of people assigned to the task. This schedule assumes that based on the calculation in the previous chapter (2.5 person years), eight people would need to be working on this task simultaneously for the four months scheduled. This task could be divided in boroughs and integrated in a final stage. However, as discussed earlier, this map may already exist.

Some contingency has been built in at the end of Phase 2, as from experience this is the most difficult phase.

Phase 3, shown in black, represents a tendering procedure, should TfL wish to proceed with the full trial. With the aid of ITS and MIRA, tendering documents and contractual arrangements would be developed and the tender placed in the European Journal. Following the hiring of the desired contractor, the fitment of the fleet can commence.

Phase 4, shown in **orange**, is a rough estimate, and will depend entirely on the system under consideration, the contractor chosen and the number of vehicles to be fitted.

Phase 5, shown in **pink**, depicts the operational stage. Support could be undertaken by the contractor chosen in Phase 3, as a kind of warranty service. During this phase, surveys would be conducted on user attitudes and data collected and analysed on speed compliance.



Phase 1
Phase 2
Phase 3
Phase 4
Phase 5
Consultation with vehicle manufacturers
Consultation with map providers
Consultation with leasing companies
Source/purchase mule vehicle
Initial ISA sytsem specification
Specify data collection
System build (HW and SW)
Initial trialling of ISA London
Installation of ISA in a Prius
Approval of system
Manufacture of 3 further units
Installation in 3 further vehicles
Road trialling
System approval
Collate speed limits
Develop speed limit database
Creation of speed limit map
Contingency
Decision point 1
Produce tender documents
Tender process
Decision point 2
Build and test fleet
Contingency
Identify drivers
Running of the trial fleet
1-Jan
1-Apr
30-Jun
28-Sep
27-Dec
27-Mar
25-Jun
23-Sep
22-Dec
21-Mar
19-Jun
17-Sep
16-Dec

#### *6.3.7 Cost*

Estimated costs for Phases 1 and 2 are of the order of £156k. This does not include overhead or the possible involvement of say Toyota. If Toyota were to join as participants, while this may be beneficial for technical know-how and later support, it may mean significant communication overhead and resource requirements. There is some uncertainty about the cost and resource of providing the in-vehicle software and hardware needed to identify position and speed limit. A likely solution would be to collaborate with a satellite navigation system provider. Such a provider would modify their standard navigation system to provide the additional feature of "reading" the in-vehicle map for speed limit. As stated earlier, an update facility would be desirable.

Also excluded is the cost of developing the speed limit database for Greater London As discussed in section 5.1, a reasonable estimate is 2.5 person years to develop such a map from scratch. Subsequent updating of that map has two elements:
1. Revising the information database. This should not cost any substantial amount provided cooperation on information provision can be obtained from the boroughs and provided the map software has been specified to allow easy updating.
2. Transmission of the revised information to the vehicles. Here the main costs will be the yet to be established telephone charges.

Costs for the later phases, in particular Phases 4 and 5, are unknown at this stage. They would be established via a call for tenders.

#### *6.3.8 Predicted collision savings*

Once again, the predicted reduction in injury accident involvements for the TfL fleet would be 19.3%. Since the actual safety record of these vehicles is not known, it is not possible to calculate the actual predicted reduction.

## 6.4 ISA for private motorists

The largest safety benefits would be obtained by encouraging the general adoption of ISA by London's motorists. Of course adoption would be heavily influenced by:
1. System costs, and
2. Incentives.

As regards system costs, our best estimate of unit costs is shown in Table 3. They presume purchase in fairly large quantities, i.e. hundreds.

**Table 3: Unit costs for ISA sub-systems**

| Sub-system | Cost |
|---|---|
| Location module<br>Basic (GPS only)<br>Advanced (navigation-based) | <br>£200 – £300<br>£500 – £700 |
| Map update function (3G phone card) | £100 |
| Control intervention | £500 |

These unit costs result in the total cost of ISA units shown in Table 4. A basic intervening ISA system has been excluded because of likely reliability problems. Provision of monitoring or recording functionality would increase unit costs but without such monitoring it would be impossible to gain an assurance that equipped vehicles were actually obeying the speed limits

**Table 4: Unit costs for ISA system**

| | Advisory ISA | Intervening ISA |
|---|---|---|
| Basic | £300 – £400 | N.A. |
| More advanced | £600 – £800 | £1100 – £1300 |

Given such prices, it is not unreasonable to suppose that substantial numbers of London motorists could be persuaded to buy and use ISA provided that some incentives to such purchase and use were offered. Incentives could take the form of:

- Discounts on the cost of on-street parking
- Reduced price of public transport via concessions on the Oyster card
- Reductions in the congestion charge for entering central London (as already provided for environmentally friendly vehicles)

An additional incentive might be reductions in insurance premiums. This might be particularly attractive to fleets including those fleets that self-insure their vehicles.

What scale of incentive would be required to persuade motorists to equip their vehicles is at present unknown. Investigation of this issue would require an additional study in which a gaming approach (stated preference) was used to elicit Londoners' willingness to pay.

The safety impact of voluntary adoption of ISA by the general public would of course depend on the scale of take-up. Given the approximate risk of one injury accident per 60 vehicle years for Great Britain, one might expect a baseline of 16 injury accident involvements per 1000 equipped vehicles per year and a reduction of 3 involvements per year with ISA.

# 7. CONCLUSIONS

Intelligent Speed Adaptation has now reached the point where it can move from research into general implementation. The long period of research has confirmed the system's benefits and the long period of development has ensured both a standard architecture and sufficient technical maturity to permit real-world application.

Three complementary forms of implementation of ISA in London are proposed. They are:

1. Implementation in buses and taxis
2. Implementation on TfL's own fleet
3. Encouragement of adoption by private motorists using a generic ISA coupled with an incentive programme.

Further study will be required to:

- Refine systems for buses and taxis
- Design an ISA for TfL's fleet
- Investigate the level of incentive required to promote ISA among private motorists
- Specify a "generic" ISA suitable for installation in private cars and assist in drawing up a call for tender to provide the equipment

The safety impact of ISA adoption will, in the long term be substantial. However, given the time required to further specify and design ISA for any of the three types of implementation, it is unlikely that there will be substantial contribution from ISA to achievement of TfL's safety targets for 2010. ISA has the potential to make an impact thereafter.

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# Appendix 1
# Overview of previous ISA trials

The table below summarises the main field trials with ISA. In addition to describing the scale of the study and the type or types of ISA tested, it presents the main findings on safety benefits and disbenefits.

| Trial | ISA functionality | No. of drivers | Vehicles Used | Road types tested | Trial length[6] | Data collected | Results | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Safety benefits | Negative effects | Attitudes |
| France #1<br>1982 | Driver-set limiter | 12 | 1 | Various | 1 drive of 200km | Observations and interviews | | Speeds tended to be set above limit | |
| Sweden #1<br>1991 | Speed limit display<br>Speed limiter (active throttle with no override possibility) Limit set to 50 km/h | 75 | 1 Volvo 750 | Urban | 1 hour | Speed<br>Travel time<br>Red running<br>Car-following<br>Interactions<br>Conflicts<br>Emissions<br>Opinions | General speed reduction<br>Less red running<br>Less conflicts | Increased speed on approaches and in turnings<br>Deteriorated behaviour in interactions | Improved after testing the system |
| Eslov<br>1997 | Speed limit display<br>Speed limiter (active throttle with no override possibility) | 25 | Various drivers´ own cars | Urban | 2 months | Speed<br>Travel time<br>Interactions<br>Conflicts<br>Emissions<br>Opinions | General speed reduction<br>Improved behaviour in interactions | Travel time increase 5% | Improved after testing the system |
| MASTER<br>1997<br>Sweden,<br>NL,<br>Spain | Speed limit display<br>Speed limiter (active throttle with no override possibility) | 20<br>20<br>20 | 1 Toyota corolla | Urban<br>Rural<br>Motorway | 1 hour | Speed<br>Travel time<br>Time-gap in Car-following<br>Giving-way behaviour<br>Interactions<br>Driver workload<br>Opinions | General speed reduction<br>Speed on approaches smoother<br>Car-following Improved (30-50 kph roads) | Car-following Deteriorated (70-90 kph roads)<br>Experienced increase in frustration and decrease in performance<br>Travel time increase 7% | The majority of the subjects accepted the speed limiter as a driver-operated system. Half of the drivers would accept the limiter voluntarily in their cars. |
| UK EVSC<br>1999 | LCD displaying speed limit<br>Digital road map<br>2 ISA types (Mandatory and Voluntary)<br>Ignition retard<br>Fuel supply reduced<br>Braking applied if necessary | 24 | 1 Ford Escort | Urban<br>Rural<br>Motorway | 3 hours | Speed<br>Braking<br>Retardation<br>System use<br>Acceptability<br>Workload<br>Observations | Excessive speeding reduced<br>Improved following behaviour<br>Less abrupt braking | Drivers experienced higher time pressure | Drivers preferred the Voluntary ISA |

[6] This refers to the amount of exposure each driver had to ISA. In some cases only an approximate figure is known.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Umeå<br>2001 | Informative ISA<br>A light and auditory signal presented if speed limit exceeded. | 4500 private motorists, professional drivers and public transport | | | | | General speed reduction measured at the roadside | | |
| Lidköping<br>2001 | GPS and digital road map<br>Informative and/or active support | 280 vehicle, 150 with advisory system, 130 with active gas pedal system | Private motorists, companies and local authority vehicles | | | | | | |
| Borlänge<br>2001 | GPS and digital road map. Warning ISA. | 400 vehicles | Private and fleet drivers | | | | | | |
| Lund<br>2001 | Digital road map<br>Speed limit display<br>Active throttle | 284 vehicles | Various drivers´ own cars | Urban | 5-18 months | Speed<br>Speed variance<br>Travel time<br>Time-gap in car-following situations<br>Giving-way behaviour<br>Workload<br>Opinions<br>Voluntary usage<br>Emissions | General speed reduction<br>less speed variation<br>Behaviour towards other road-users improved<br>Distance to vehicle in front increased on arterial roads | Delegation of responsibility where the system is not active | The test drivers generally think that the AAP is efficient for increasing traffic safety and experience it as a support in car driving. Driver-acceptance of such a system is high within built up areas.<br>Those who would need it the most like it the least |
| Tilburg<br>2000 | GPS and digital road map<br>LED display indicating which speed limit was activated.<br>Mandatory - fuel restriction (and no haptic throttle) | 479 drivers<br>20 bus drivers | 20 VW Boras<br>1 passenger bus | Urban<br>Rural | 1 year | Speed<br>Speed variance<br>questionnaires | Average speeds lower<br>Less speed variation<br>ISA had calming effect of driving.<br>Less overtaking.<br>Greater following distances.<br>25% reported slowing down to below the speed limit.<br>Passenger bus results similar to test cars – effects of ISA dampened with frequent stops and relatively easy acceleration | Majority felt negative when limited to 18km/h<br>Driers reported experiencing aggressive behaviour form other drivers at start of trial. This decreased with increased publicity. | 52% agreed ISA increased pedestrian and cyclist safety.<br>36% agreed ISA was safer for driver.<br>Up to 65% test drivers supported ISA, 30% other reference groups opposed.<br>Appreciation highest for 80km/h roads.<br>Information and communication had large effect on acceptance. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Aalborg 2001 | Speed limit display<br>Digital speed limit map<br>Advisory<br>GPS, dead reckoning and map matching, digital voice warnings | 24 | 12 on board units fitted to drivers car | Urban | 6 weeks | | Speeds reduced<br>Decline in 85% for speed violations<br>Larger decline in speed violations in rural areas than urban areas.<br>Drivers more aware of their speed following experience.<br>Risk awareness did not vary effect of ISA. | 2 drivers expressed defiance and increased speed. | Improved after testing the system - 15 out of 20 more favourable to ISA following experience.<br>ISA not perceived to limit drivers freedom.<br>19 out of 20 believed ISA could be used for selected groups.<br>Almost all would prefer speed limits to increase. |
| Finland 2001 | GPS, GSM for data transfer and digital road map<br>Speed limit display<br>Informative (auditory warning)<br>Mandatory (block on gas pedal)<br>Recording (% time spent speeding displayed and recorded) | 24 | 1 Toyota Corolla | Urban<br>Rural<br>Motorway | 1 route (17.6km) x4 | | All systems reduced time spent speeding<br>Mandatory had greatest effect<br>No significant difference in driving times across systems | Mental demand highest for mandatory and recording system<br>Effort, frustration and insecurity levels greatest for mandatory system | Information of speed limit very useful<br>Informative voice signal annoying and too rigid<br>Mandatory system considered irritating and dangerous but deemed most effective<br>Recording considered desirable. |
| Ghent | GPS and digital road map active accelerator pedal (IMITA) | | 34 cars and 3 buses | | | | | | |
| ISA-UK 2004-2007 | GPS, dead reckoning and map matching, Mandatory, opt-out | | 20 Skoda Fabias | | | | | | |
| France | Advisory<br>Voluntary active (driver enables)<br>Mandatory active (overridable with a kickdown) | | 20 Renault Lagunas | | | | | | |
| SafeCar (Au) | LCD displaying visual warning when 2km or more over speed limit.<br>Actively Supporting ISA.<br>2 stage warning: visual speed limit icon and single auditory tone followed by flashing visual icon and haptic feedback.<br>Digital roadmap and GPS. | 23 | 15 Ford Falcons | All road types in Melbourne metropolit-an region | 16,500 kms (approx 5-11 months) | Speed<br>Following distance<br>Braking<br>Acceptability<br>Usability<br>Workload | Reductions in mean and $85^{th}$ percentile speed and speed variability.<br>No significant change in travel time. | Drivers experienced some frustration due to speed limit inconsistencies in the ISA digital map | ISA system rated as being useful, effective in reducing speed and socially acceptable |

| Variable | System | | | | |
|---|---|---|---|---|---|
| | Information via display | Feed-back | | "Intelligent" gas pedal | |
| | | Direct | Accumulated (tachograph) | Voluntary | Mandatory |
| Speed behaviour | Improved – HUD (Rutley 1975)<br>Deteriorated (Nilsson & Berlin 1992)<br>Deteriorated (Almqvist & Towliat 1993) | Improved (Kuiken 1996)<br>Improved (De Ward et al. 1994, 97, 99)<br>Improved (Brookhuis & De Ward 1997) | Improved (Larson et al. 1980)<br>Improved (Wouters & Bos 2000) | No change (Saad & Malaterre 1982) | Improved (Persson et al. 1993)<br>Deteriorated at junctions (Persson et al. 1993)<br>Improved (Comte 1996)<br>Improved (Almqvist & Nygård 1997)<br>Improved (Comte 1998a)<br>Improved (Comte 1998b)<br>Improved (Várhelyi & Mäkinen 1998) |
| Number of glances at the dashboard | Deteriorated (Nilsson & Berlin 1992) | – | – | – | – |
| Headway | – | – | – | – | Improved (Persson et al. 1993)<br>Improved (Comte 1996)<br>Deteriorated (Comte 1998b)<br>Improved on urban roads (Várhelyi and Mäkinen 1998)<br>Deteriorated on rural roads (Várhelyi and Mäkinen 1998) |
| Gap acceptance | – | – | – | – | Deteriorated (Comte 1996) |
| Behaviour in interactions | | | | | Deteriorated (Persson et al. 1993)<br>Improved (Almqvist & Nygård 1997)<br>No Change (Várhelyi & Mäkinen 1998) |
| Mental workload | – | Increased (De Ward et al. 1994, 97, 99)<br>No effect (Kuiken 1996)<br>No effect (Brookhuis & De Ward 1997) | – | – | Increased frustration (Comte 1996)<br>Increased frustration (Várhelyi & Mäkinen 1998)<br>No effect (Comte 1998b) |
| Acceptance | Decreased (Comte 1998b) | Good (De Ward et al. 1994, 97, 99)<br>Good (Vägverket 1997) | Initially low, increased with time (Larson et al. 1980) | Low (Saad & Malaterre 1982) | Improved (Persson et al. 1993)<br>Improved (Almqvist & Nygård 1997)<br>Low (Comte 1998a)<br>Fairly good (Várhelyi & Mäkinen 1998) |

# Appendix 2
# ISA systems currently on the market

This appendix provides an overview of hardware currently on the market.

## A. Limit Advisor (Imita)

Imita's Limit Advisor is a Swedish active speed assistance system that provides feedback from the accelerator to the driver about his driving speed, Figure 5. When the speed limit is exceeded, a resistance from the accelerator is felt, which informs the driver that he has reached the permissible speed. This resistance works as speed assistance, if you lean on this the car will automatically follow legal speed limits. The driver can override this feedback at any time.

When the driver has reached the speed limit, the system cuts off acceleration, which can only be regained by applying a kick-down manoeuvre. Both these systems are static, i.e. while driving the driver has to preset the speed limit manually.

By using GPS (Global Positioning System) signals, Limit Advisor can achieve intelligent speed limitation with the ability to locate a given speed limit within an accuracy of 10 meters.

Four Swedish cities were involved in the biggest traffic safety study: Umeå, Borlänge, Lidköping and Lund. During the course of the project, almost 450 vehicles where equipped with the Limit Advisor and more than 700 drivers gave their opinion.

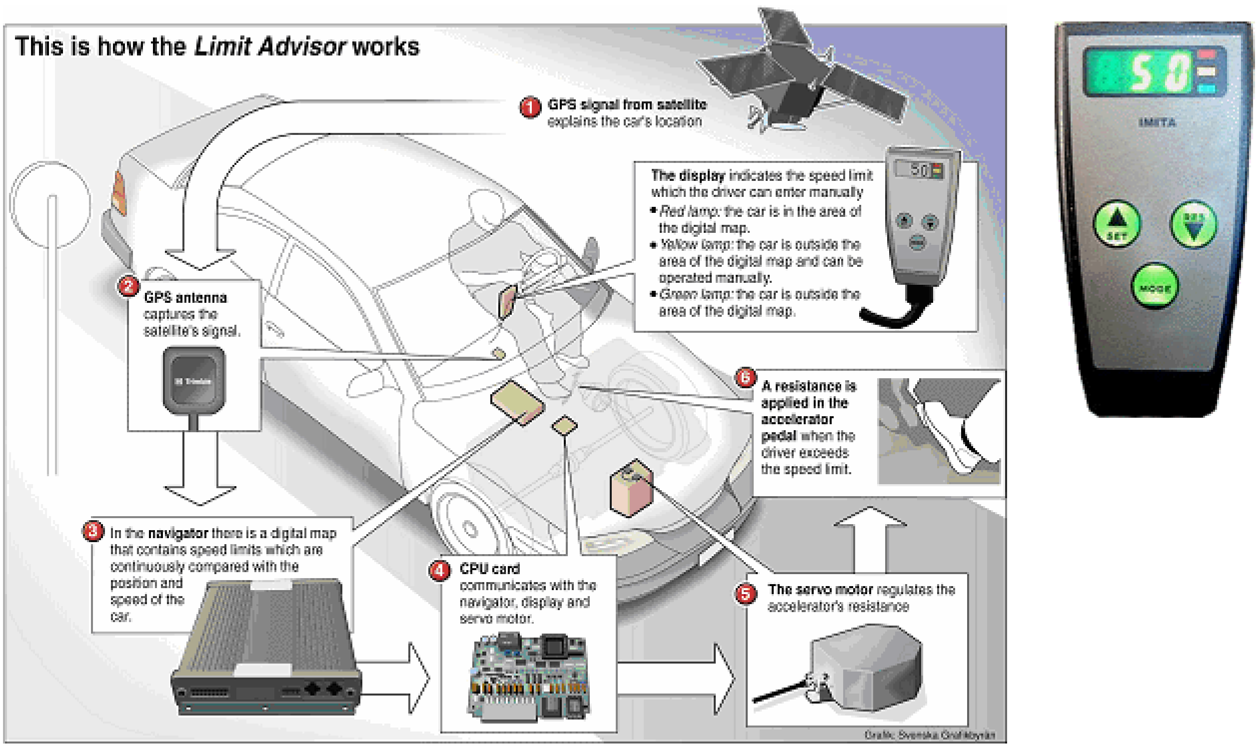



**Figure 5: How the Limit Advisor works**

### Potential problems with the IMITA system

A number of potential problems have been highlighted with the Imita system, particularly following the trials in Belgium. These have been summarized as follows:

- Mechanical reliability. The system's lifetime is shorter than that of the vehicle's lifetime. Among the 37 participating vehicles and within the 14 months of the trial, eight servomotors (four among them in the three city buses) had to be replaced, which represents more or less half of the systems installed. The reason why they all had to be replaced is the continuous presence of the counter pressure in the pedal creating excessive wear in the synthetic gears transmitting the motor power. It mainly occurred in vehicles with an intensive usage (city buses or private cars with a high annual mileage).
- Safety. The counter-pressure is the default state of the limiter and whether this is safe when the system is not working properly is debatable, since the driver has to then deliver a continuous physical load when driving the vehicle. The pressure is constant and can neither be adjusted statically (according to the driver's physical strength) nor dynamically (a pressure proportional to the difference between the actual speed and the speed limit).
- Compatability. Not all vehicles are suitable for installation of the Imita system. Depending on the pedal hanging and the free space under the bonnet it is sometimes impossible to install the Limit Advisor in either used or new cars or vans. According to a listing made by IMITA, around 50% of the cars on the 2002 Belgian market would be suitable for an installation of the Limit Advisor M2002, 25% would be less suitable (problems expected) and installation is not recommended in the remaining 25%. Among the latter are old, new, lower class and higher class vehicles. It is likely that compatability will decrease even further in the future.
- Map problems. The digital map capacity was too small. With a unidirectional speed limit as sole attribute, the map's maximum capacity was around 7000 road segments, which is few even for the relatively small area tested in the Ghent trial (8x4 sq.km.). The absence of online update possibility is another limitation of all static digital maps since the design and the speed limits of the road network quickly become obsolete. Also, the system is incompatible with dGPS.
- Inaccurate data logging. The main problem is the absence of a logged binary value describing the speed limiter's on/off status. Such a value would have allowed - among other things – the comparison of driver's behaviour before and after ISA triggers. This could also not be derived from the logged speed since two different odometer sensitivities had been used for functional and logging purposes. Furthermore no logged data gave in real time an indication of the GPS positioning accuracy. The use of two separate sampling frequencies inside and outside the digital map area made the comparison of driver's behaviour before and after crossing the map border more difficult. The RPM signal, when available in the car, was only logged in the map area.

The Hungarian ISA trial involving the *Limit Advisor M2002* reported far fewer mechanical problems (3 minor problems in total) than the Belgian trial. The possible reasons are a shorter testing time (1 vs. 12 months active accelerator), fewer vehicles (20 vs. 37), a newer version of the device, uniformity of host vehicles (nearly all Suzuki vs. a large range) and the installation and maintenance operations made by an official dealer.

## B. Continental

Active Distance Support (ACDIS) is a driver assistance system from Continental Temic which combines an Adaptive Cruise Control function with the ability to maintain mandatory or freely selectable speeds, Figure 6. Even with the system deactivated, the force feedback gas pedal still warns the driver when the vehicle in front is no longer at a safe distance. In its most sophisticated form, ACDIS can actively shorten stopping distances and recommend safe speeds for the prevailing weather conditions. ACDIS systems will be making their first appearance in production models at the end of 2005.

The driver can, however, overrule ACDIS at any time by overcoming a distinct pressure point as the pedal is depressed. This also applies when ACDIS is set to maintain a speed limit. If the driver wants to exceed the pre-set limit, all he has to do is hit the gas hard. So the driver always retains full control over the speed of the vehicle.

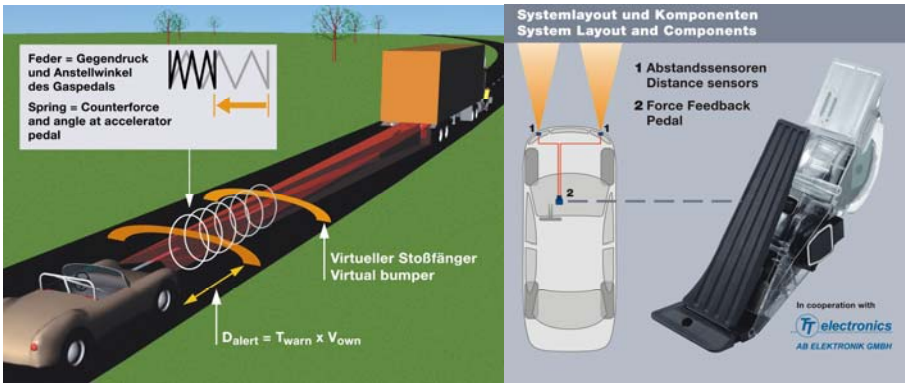



**Figure 6: The ACDIS system**

Continental is only supplying OEMs so the system is not appropriate for retrofitting. Also, there is no incorporation of a positioning system.

## C. Siemens VDO

In all intervening ISA systems a decision has had to be taken on where in the standard vehicle hardware and control architecture the ISA control acts between the driver and the engine control system. In the Imita Limit Advisor system described earlier this is an intervention with the mechanical linkage or throttle cable between the accelerator pedal and the fuelling system for the engine. In later work such as the DfT-funded ISA-UK trials this intervention is with the electronic linkage between the accelerator and the engine management system. This takes advantage of modern throttle-by-wire design. However it does require the construction of a bespoke intervention interface as none were previously on the market.

Recent changes to legislation regarding speed limits applicable on light goods vehicles have developed a market for an aftermarket adaptable speed limiting device. This has been addressed by Siemens VDO who have produced a device to be retro-fitted to vehicles that require a speed limiting function. This generic interface device also provides an intervention interface to throttle-by-wire vehicle control systems. The device is called Pedal Interface II and is illustrated in Figure 7.

**Figure 7: VDO Pedal Interface II**

This device can be inserted into the throttle-by-wire wiring to allow additional control of throttle actuation. This can generate both cruise control and speed limiting functions, with up to 7 specific speed limits capable of being set. While this device alone is not ISA, it will facilitate easier controlled interfacing with a wide range of modern vehicles via a fully developed and tested product. To generate a full ISA limiting capability such a device would need to be additionally interfaced to a sub-system having GPS, digital map and speed limit database capability. It is believed that this type of device may make ISA implementation easier on a wide range of vehicle types. It is perhaps worth noting here that virtually all new car models come with throttle by wire, so that this feature will soon be standard in the vehicle fleet.

## D. System Design for ISA-UK Trials

The initial feasibility stage of the ISA-UK project considered all of the issues and constraints that would influence how ISA functionality could be achieved. A system specification was produced through an iterative process that included both the engineering design team and the driver behavioural research team. The process was a series of facilitated and documented discussions that produced two live definition documents. These documents formed the basis for the manner in which ISA was to be implemented, the requirements for the test fleet vehicles and the data formats necessary for system functioning, data recording and analysis procedures to be carried out.

These documents were:

- ISA User Needs issue 2e, 19 Mar 2003
- ISA Data Specification issue 15.6, 28 July 2003

The first of these was the result of formal User Needs analysis carried out by the joint MIRA/ITS ISA research group. This process identified the project and organisational needs for the ISA “system” to allow successful and effective performance of the goals of the ISA project. This User Needs document outlined 183 separate user needs.

The second of these was derived from additional discussions between the MIRA/ITS teams and formed the definition of what the ISA system outputs were to satisfy the project User Needs defined above, and the system inputs required from the GPS and Digital Map platform sub-systems that supported the ISA system design.

***Selection of Host Vehicle***

Some initial scoping criteria were agreed at the outset for desirable vehicle characteristics for a “public” long-term trial. These criteria were:

- Small family car
- Large enough for flexibility
- Small enough for city driving
- Adequate power for pleasant driving experience
- A car that most people would be pleased to drive for 6 months trial period

In order for this vehicle to be useable as day-to-day family transport it was also thought that it was necessary to have the following “capacity” features:

- Varying personnel sizes requires good all round visibility and seat/steering wheel adjustment
- Two adults comfortable in the rear seats
- Not intended for family holidays but good boot space desirable

In addition there were other “perception” factors thought to be of importance. These were:

1. Need to present a relatively “new” car to the subjects who will be driving during the later part of the trials (i.e. up to and including 2005)
2. ABS, airbags, additional safety features, etc offers the subjects the best vehicle for this trial
3. Use the most up to date technology
4. Respectable brand/Enhanced image from the start
5. Impression of refinement with a quiet engine and smooth ride

There were also technical features that the vehicle should have. These were:

- Electronic throttle
- ABS, Stability Control or Traction Control
- Suitable screen or space for screen
- Space for control boxes
- Ability to drive at 30 mph in top gear
- At least 3 years to model replacement
- Safety / Visibility / Interior design

The availability of an electronic throttle was a crucial aspect within the vehicle features. This was selected as the most appropriate intervention method in interfacing to the engine power demand. In this respect the concept was to intercept the driver pedal demand and create an ISA pedal demand based upon speed limit information available within ISA. This arrangement would allow the engine ECU to ensure correct emissions. This approach was selected over an alternative, used in other ISA trials, where pedal intervention was via an interface to the accelerator cable system which could be both crude and costly.

The availability of some additional vehicle control system (ABS etc) was also thought beneficial as this would enable a single interface to overall vehicle stability control, and the possible direct control of braking system.

Another factor was the ability to mount or utilise a visual display within the vehicle to provide the driver with information on the status of the ISA system. An elegant solution would have been to use an existing display, but it was soon apparent that an additional display would be required. Such a display had to be capable of being installed in such a way that it was integrated within the existing instrument panel and visually accessible to the driver. The display and installation should also have a “professional” appearance to optimise driver reaction to system and should have a robust design to ensure a three year operational life.

When these desirable requirements, and others such as volume requirements for equipment installation, were taken into account. A shortlist of potential host vehicles was drawn up.

A market survey was first carried out to establish which vehicles satisfied the main technical requirement, i.e. of having an electronic throttle, and the other overall criteria indicated above. Following further analysis a small group of final contenders for the ISA host vehicle was assembled and subjectively evaluated by the project team. The final selection was made from the following:

1. Renault Laguna
2. Skoda Fabia
3. Vauxhall Astra

A vehicle check list/assessment form was designed and a joint ITS/MIRA panel carried out driving and evaluation trials. No initial criteria weighting was used during these assessments as the overall assessment were discussed by the group after the trial. The final selection for the ISA Phase 1 development, and subsequent fleet installation was made of the Skoda Fabia Elegance 1.4 litre estate. This vehicle being judged overall as the most appropriate package to address the declared needs of the ISA trial. The vehicle model is illustrated in Figure 8.

**Figure 8: ISA Fleet Vehicle**

It should be noted that, at the moment, modifications to a vehicle to enable a satisfactory intervening ISA have to be developed using equipment that is tailor-made for the specific vehicler. There are as yet no fully satisfactory after-market kits available, though this situation is starting to change (see page 62)

### *Human Machine Interface (HMI)*

As the primary interaction of the Phase 2 trial subjects with ISA will be through the controls and displays available to the driver plus the "feel" of the control intervention of ISA particular attention was paid to this aspect of design evaluation. Recognition of population stereotypes with regard to activation/de-activation, colour coding, handedness etcetera were followed where possible and achievable.

The goal was to deliver these additional interfaces to the driver in a manner and state consistent with the original equipment and provide them in a form that was compliant with current regulations, standards and guidelines relevant to in-vehicle equipment. To support this a review of current performance standards/design guidelines was undertaken and the proposed ISA system HMI was reviewed and deemed to be in support of these and practical experience gained in the earlier DfT project External Vehicle Speed Control (EVSC) project with regard to interface acceptability.

The following items have been implemented:

Controls:
- Thumb operated – ISA control enable/disable buttons on the top surface of the steering wheel
- Finger operated – ISA system overall disable "stop" button in the central control cluster.
- Foot operated – ISA system disable via "kickdown" via full depression of the accelerator pedal.

Displays:
- Visual Display – an ISA status/information display panel located centrally in the vehicle instrument panel.
- Visual Display – via control illumination/position of all ISA controls
- Auditory Display – an ISA status display giving feedback on system status/activation.

The overall concept was to integrate ISA system components and functionality into the base vehicle so that the user would feel that the system had been installed as original equipment. It was acknowledged that it was necessary to package the additional ISA system hardware in such a manner that it did not compromise "normal" storage space within the vehicle, as well as minimising the potential for tampering. Therefore, a goal was to design and install hardware that was stylistically comparable to the manufacturer's equipment and was compatible with the interior layout. For this reason space behind the glove box and in the boot spare wheel well is utilised to allow the system to be hidden.

### *Additional Equipment for the ISA System*

The OEM accelerator pedal demand (i.e. pedal angle) is determined by a twin potentiometer sensor unit. To facilitate ISA control intervention an interface has been provided between the OEM pedal sensors and the Engine Control Unit. This enables the throttle demand requested by the driver to be routed through the ISA control system.

The standard radio aerial has been replaced with a combined GPS/GSM and radio antenna. An additional LCD is mounted centrally within the instrument cluster and can display a wide range of ISA system status and Speed Limit information. It is easily seen through the steering column and has character sizing, contrast and format to the other OEM supplied LCD displays in the cluster. The only other visible elements of the ISA system accessible to the driver are the two illuminated steering wheel mounted ISA accept and reject buttons (one green and one red) and an extra button set within the dashboard (see Figure 9 and Figure 10). It should be noted that these controls are colour coded and in the case of the override control utilise OEM switchgear of a comparable style and finish.


**Figure 9: Steering wheel-mounted buttons and ISA screen**

An analogue I/O interface board is fitted to the rear of the glove box and an electrically driven pneumatic pump is housed in the engine bay (Figure 11) to power an actuator fitted to the brake pedal (Figure 12).


**Figure 10: ISA Override button**


**Figure 11: Underbonnet mounting of air compressor**

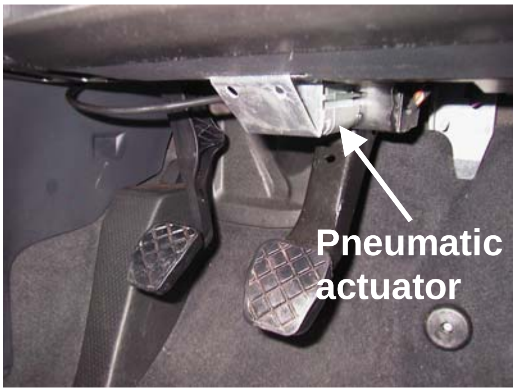



**Figure 12: ISA Brake actuator**

Two embedded computers, a proprietary sensor box that houses a GPS receiver, a yaw sensor, a speed pickup and direction of travel signal, together with the associated power supplies are all housed in a unit installed in the well next to the spare wheel (see Figure 13).

A major part of the final installation was the signal and power cabling between the driver's location displays, controls and control modules and boot/roof mounted controllers and processors. An additional wiring loom was designed and installed to provide this.

**Figure 13: The main ISA equipment installed under the luggage storage area**

### *General ISA Architecture*

The overall architecture of the ISA system is illustrated schematically in Figure 14. The system undertakes speed control and data acquisition tasks through four modules:

1. Location
2. Interpretation
3. Command
4. Control

The Location Module receives inputs from the GPS receiver, together with direction and distance data. Fused data relating to location, direction and time is processed by the Navigation computer. Using the digital map the current link is identified enabling the speed limit applicable to the current vehicle position to be found. This speed limit, along with other data for data logging such as location, is passed to the Command Module. The Command Module receives inputs from the driver and relays them together with the speed limit to the Control Module. When ISA control is active the primary function of the Control Module is to compare the road speed with the current speed limit and reduce speed if necessary through the throttle and the brake. The Command module also undertakes the data logging functions and drives the HMI module.

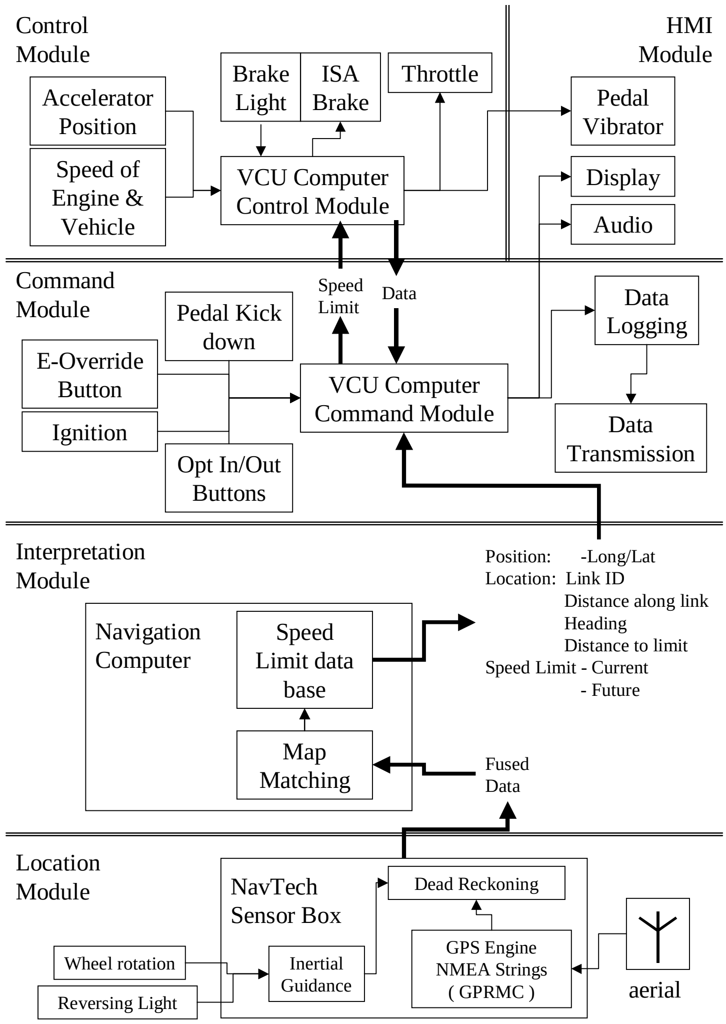



**Figure 14: ISA system implemented on the ISA fleet cars**

***Calibration of the ISA system***

As part of the conversion of each ISA car the speed of the ISA system is calibrated. A GPS satellite-based VBOX system from Racelogic provides the actual vehicle speed. The aim is to adjust the ISA control speed to correspond with the appropriate speed limit i.e. when the current speed limit is 30mph the ISA system is able to limit the vehicle to a maximum speed of 30mph. Checks are undertaken at 20, 30, 40, 50, 60 and 70mph. However, since there is some non-linearity in the system it is not possible to achieve a perfect result. Travelling up and down hill will also have a small effect on the speeds achieved. It should be noted that the vehicle speed used by the ISA system is derived directly from a frequency proportional to speed signal generated by the car. This is not the same as the speedometer reading. Speedometers are specified to show the actual speed -0%, +10%. This means that when a car is travelling at an actual speed of 30 mph the speedometer could be reading between 30mph and 33mph.

***Operational States of the ISA System***

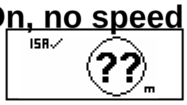
When the vehicle speed is much less than the current speed limit, the driver's throttle demand is passed straight through to the engine ECU. When the vehicle speed is within 10% of the current speed limit the ISA system calculates the throttle demand to maintain the vehicle speed at the speed limit, compares this demand with the demand from the driver and passes the smaller value to the engine ECU.

The following descriptions illustrate the various states of the ISA system as displayed to the driver following start-up of the vehicle.

**ISA Waiting**


At the start of a journey the ISA waiting display is shown. This indicates that the ISA system is waiting for a message from the navigation system.

**ISA On, no speed limit**

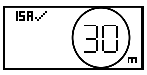



When the ISA system is unable to establish a speed limit for the current link the display will show two question marks.

There are several reasons for the system being unable to display a speed limit:

1. The vehicle is not on a recognised link in the digital map such as a car park or a private drive
2. The current link does not have a speed limit associated with it (i.e. outside the speed-mapped area)
3. The navigation system is trying to establish which link the vehicle is on.

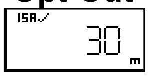
**ISA On**



The display shown to the driver when the ISA system is active and the speed limit is 30mph is shown above. In order to limit the vehicle to the desired speed limit the ISA system intercepts the signal sent from the electronic throttle pedal to the Engine Control Unit (ECU). The ISA system can review this signal and determine the value that is required to limit vehicle speed to the maximum speed limit set for the road. The ISA system compares the current road speed with the speed limit. If the road speed exceeds the speed limit then the throttle signal to the engine control unit is reduced. If the road speed exceeds the speed limit by more than 2% then the ISA brake is applied until the road speed falls to the speed limit.

If the driver tries to exceed the speed limit by increasing the throttle demand, the ISA system will activate a vibrating motor fitted to the accelerator pedal when the driver demand exceeds the calculated maximum throttle demand by 40%. This gives the driver tactile feedback that the throttle demand requested is in excess of that required by the current speed limit.

**Opt-Out**

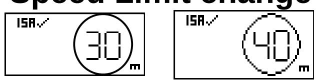



If the driver wishes to exceed the current speed limit, perhaps to pass a slow moving vehicle quickly, he can opt-out of ISA control by either pressing the red button on the steering wheel or by depressing the throttle pedal fully to reach the “kick-through” position. When the opt-out signal is received the ISA system responds by generating a sound, removing the circle from around the displayed speed limit and passing the driver throttle demand directly to the ECU.

ISA control can be restored in two ways:

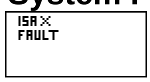
1. The driver can press the green button (opt-in) to reinstate control to the prevailing speed limit.
2. The vehicle speed falls below the current speed limit and the system automatically restores speed control.

**Speed Limit change**



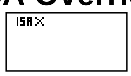

When the vehicle passes from one speed limit to another the driver is informed visually through the ISA display and by the new speed limit sound. The change in ISA display moving from a 30mph limit to a 40mph limit is shown in the figure above.

**ISA System Fault**




If certain fault conditions are identified during a trip then ISA control is suspended. The driver is informed visually through the ISA display and by the ISA Fault sound. The fault can only be cleared and ISA control returned by terminating the current journey and starting another through key-off and key-on.

**ISA Override**




The ISA override button, a modified Skoda switch, is clearly located directly above the vehicle radio/cassette on the control console, next to the ASR and below the emergency hazard flasher buttons. It is for overriding the ISA system in the unlikely event of a failure occurring with the system. This should only be used in an ISA failure situation and should not be used to opt-out of ISA control in normal driving.

If the override button is pressed then all normal controls return and there is no speed control. It should be noted that logging of the various locations, speed limits and vehicle speeds continues. The override button is reset at key-off.

***Data recording***

The data to be recorded is specified in the ISA Data Specification issue 15.6, 28 July 2004. Three files are produced for each trip, where a trip is defined as Ignition key-on to ignition key-off. These files are:
Summary File
Main Data File
Error Log file

All of these files are stored on the hard disk that forms part of the Data Logging system. All of the files are duplicated on a second hard disk to reduce the potential impact of data loss due to failure of a hard disk. The available space on each disk is checked during each trip. If the capacity has fallen below 20% of the full capacity a warning is included in the summary file.

Although the summary file is recorded on the on-board hard disks it also sent as an SMS message at the end of each trip to the ITS server at Leeds.. This summary data file contains 23 variables with 105 characters.

The main data file is a continuous ASCII stream. It contains three parts:

1. Header with 13 fields
2. Main Data with 21 fields;
3. Footer with 14 fields

The data stored on the car can be downloaded at the end of each trial phase. The error log file is only used for fault investigations.

***Map***

Leeds Metropolitan District covers an area of 560 square km. The area is run by Leeds City Council and it was their Highways Department that supplied the speed limit information in the form of paper files containing Council Speed Orders.

The geographical package that was used was ArcInfo version 8.1. It was chosen because it is compatible with many data formats. The GIS package allows easy construction of point data, which would be used to position the speed limit information on the road segments.

The digital speed map that was sent to Navteq, the navigation company chosen for this project, was made up of two layers. The OSCAR Asset-Manager links layer represented by lines and the speed limits layer represented by points. The speed limits layer was constructed using the Leeds City Councils Speed Order files and the

ArcInfo programmes ArcCatalog and ArcMap. The links layer already has an attribute table constructed and that was used as a template for the attribute table within the speed limit layer.

OSCAR Asset-Manager attribute tables contains information on each of the 42,149 links. The attributes include the unique OS link identifier, feature class, length of link, form of way and the XY coordinates of that link. It had been decided that the default speed limit would be 30mph because the majority of roads within the Leeds Metropolitan District have a speed limit of 30mph. Within the links attribute table, another column was added called VALUE to incorporate this default. Every link with the default speed limit had the value 30 added, all other speed limits were 0.

The exceptions speed limit layer would take the form of points placed to the left of the corresponding road where the speed signs would be in the real world. It was also decided to place the points to the left of the road so the speed limit sign would be in relation to the direction of traffic. The position of the speed limit point would be at the beginning of the speed limit change. They could be many roads with the same speed limit but only one point added where the change actually took place. In the case of the 20mph calming zones points would be placed on the entrance and exit roads to the zone.

ArcInfo allows the user to construct the point data in a variety of ways. For this project the absolute XY coordinates option was used. This allowed a point to be placed on the map and the coordinates automatically retrieved.

Reliability of the speed limit information is an important issue for ISA-UK project. The speed limits were taken from paper speed limit orders and it was essential that these were checked to ensure they corresponded to the road environment.

Within the OSCAR Asset-Manager files there appeared to be some small roads that were not on the map which had a speed limit other than 30mph. The decision was taken to not place a speed sign on the map where the road should be, because the accuracy of the positioning could not be guaranteed. A note of the roads that were not on the map and their speed limits was supplied to Navteq, in case they had access to them.

To ensure all the speed signs were located in the correct position, any speed orders that had given their markers as house numbers were visited in the field with a detailed street plan for their exact location on the road. A field visit was also undertaken for any speed limit where doubts had been raised.

When the real-time speed limit map came back from Navteq it was checked against the Speed Order information originally collected. Navteq had also included speed limits for all motorways and trunk roads within England, Scotland and Wales. The speed limit map was loaded on to the cars' operating equipment and field checks were carried out to ensure the speed limits changed as close to speed signs as possible. In the event of a speed limit changing during the trial the capability to change the limit was available. However should a sign have moved position it was not possible to break the link to reposition the speed sign, resulting in the cars changing speed either earlier or later than the sign on the road.

# E. Conclusions

No off-the-shelf ISA exists that can be recommended for deployment in London. However, recent developments such as those from Continental and Siemens VDO indicate real products are fast coming to the market. An approach in which equipment is specifically designed for deployment in London is recommended. Given experience from the ISA-UK trials, some improvements to the vehicle design used there can be proposed:

- There should be a less time-consuming data recovery procedure (for the London trial only limited data would be required)
- The HMI should have improved clarity
- A more reliable alternative to Windows should be used
- The kick-through function is not required (users preferred the steering-wheel interface).

# Appendix 3

## Telephone survey of the London Boroughs

| Council | Switchboard | Other details | ✓ Paper point 2 point ✓✓ with co-ordinates | ✓ electronic point 2 point ✓✓ with co-ordinates | Approximate number of TMO's | Range of speeds | Non borough roads | Impending changes |
|---|---|---|---|---|---|---|---|---|
| Barking and Dagenham | 020 8215 3000 | 40mph to be changed | ✓ | | ? | 30/40 | 2 DFT | 1 |
| Barnet | 020 8359 2277 | | ✓ | ✓ | ? | 20/30/ 40/70 | ? | none |
| Bexley | 020 8303 7777 | | ✓ | ✓ | 20 | 20/30/ 40 | | |
| Brent | 020 8937 1234 | | ✓ | | 30+ | 20/30/ 40 | 1 TfL | 2 new 20mph |
| Bromley | 020 8464 3333 | | ✓ | x | 24 | 40/50/ 60 | | none |
| Camden | 020 7278 4444 | | ✓ | ✓ | 20 | 20/30 (50/50 split) | | none |
| Corporation of the City of London | 020 7606 3030 | In process of incorporating Ordnance survey points on all TMO types. Asked to reduce 20mph zones by Members. | ✓ | ✓ | 10 | 30 (90%) /20 | 4 TfL | |
| Croydon | 020 8686 4433 | | ✓ | ✓ | 25 | 20/40/ 60 | | none |

| Council | Switchboard | Other details | ✓ Paper point 2 point ✓✓ with co-ordinates | ✓ electronic point 2 point ✓✓ with co-ordinates | Approximate number of TMO's | Range of speeds | Non borough roads | Impending changes |
|---|---|---|---|---|---|---|---|---|
| Ealing | 020 8825 6000 | Charges apply. Mouchel Parkman consultants | ✓ | ✓ | ? | 20/30/ 40/50 | | |
| Enfield | 020 8379 1000 | Cost for Borough road plan with speed limit animation (CAD). Apply to H of Traffic Transportation Services, Civic Centre, Silver Street, Enfield, EN1 3XD | ✓ | | 15+ | 20/30/ 40/50/ 70 | 2 TfL 1 HA | 20mph |
| Greenwich | 020 8854 8888 | TMO (consultant) | ✓ | | 2 | 10 (tunnel )/20/30 /40 TfL/50 | 4 TfL | none |
| Hackney | 020 8356 5000 | Consultants have orders; email request for discussion with consultant | | | | | | |
| Hammersmith and Fulham | 020 8748 3020 | A few home-zones | ✓ | ✓ | 3 (20mp | 20/30/ 40/50 | 2 TFL | 1 +20mp |

| Council | Switchboard | Other details | ✓ Paper point 2 point ✓✓ with co-ordinates | ✓ electronic point 2 point ✓✓ with co-ordinates | Approximate number of TMO's | Range of speeds | Non borough roads | Impending changes |
|---|---|---|---|---|---|---|---|---|
| | | | | | h) | | | h |
| Haringey | 020 8489 0000 | Post 2000 all electronic | ✓ | ✓ | 24+ | 20/30/ 40 | 12 TfL | Yes 20mph |
| Harrow | 020 8863 5611 | | | | | | | |
| Havering | 0170 843 4343 | TMO | ✓ | ✓ | 50+ | 20/30/ 40/50/ 70 | 2 TfL 1 HA | Yes 20 |
| Hillingdon | 0189 525 0111 | | ✓ | | 30 | 20/30/ 40/50/ 60 | 2 TfL 2 HA | yes |
| Hounslow | 020 8583 2000 | | | | | | | |
| Islington | 020 7527 2000 | | | | | | | |
| Kensington and Chelsea | 020 7937 5464 | | ✓ | ? | 2+ | 20/30 | TfL | |
| Kingston upon Thames | 020 8547 5757 | | | | | | | |
| Lambeth | 020 7622 4706 | | | | | | | |
| Lewisham | 020 8314 6000 | | ✓ | | ? | 20/30/ 40 | 5 TfL inc 20mph | |
| Merton | 020 8274 4901 | | | | | | | |
| Newham | 020 8430 2000 | | ✓ | | ? | 30/40 | 2 TfL | |
| Redbridge | 020 8554 5000 | | ✓ | | 24 | 20 (lots)/3 0/40 | 3 TfL 1 HA | |
| Richmond upon Thames | 020 8891 1411 | | ✓ | ✓ | 12 | 20/40 | 2 TfL | 1 |
| Southwark | 020 7525 5000 | | ✓ | | ? | 20(30+ | ? | |

| Council | Switchboard | Other details | ✓ Paper point 2 point ✓✓ with co-ordinates | ✓ electronic point 2 point ✓✓ with co-ordinates | Approximate number of TMO's | Range of speeds | Non borough roads | Impending changes |
|---|---|---|---|---|---|---|---|---|
| | | | | | | %)/30 | | |
| Sutton | 020 8770 5000 | | ✓ | ✓ | 6 | 20/40 | 3 TfL red | none |
| Tower Hamlets | 020 7364 5000 | | ✓ | ✓ | 12 | 20/30 | 6 TfL | 3+ |
| Waltham Forest | 020 8496 3000 | | ✓ | | 12+ | 20/30/ 40/60/ 70 | 2 TfL 2 HA | Many others |
| Wandsworth | 020 8871 6000 | | ✓ | ✓ | 14 | 20/30 | 8 TfL red | 2 |
| Westminster | 020 7641 6000 | Charges apply West One Consultants | ✓ | ✓ | 30 | ? | | |