EUROPEAN RESEARCH ON ISA:
WHERE ARE WE NOW AND WHAT REMAINS TO BE DONE

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ABSTRACT

Research on driver behaviour with ISA has been going on since 1982. Initially, the concentration was mainly on small field trials to study driver behaviour in a variety of equipped vehicles. This was soon followed with a number of studies of acceptance. With the growth of interest in ISA and the gathering pace of research on the system, there has been an increasing range of studies, looking at such issues as behavioural adaptation, response to different types of system, willingness to pay, modelling of network effects and prediction of safety benefits with large-scale use. The large scale trials in Sweden, carried out in 2000 and 2001 will provide vast quantities of data, including perhaps empirical information on network effects at high rates of system penetration.

In part no doubt because of this extensive research and the clear case that has been made for the benefits of ISA, the ground has shifted. ISA implementation, which was originally perceived as a radical measure promoted by a fringe of safety researchers in now considered virtually inevitable even by the car manufacturing industry. However, the research is by no means complete and there are a considerable number of important aspects and issues that remain unexplored. For example, there has been relatively little systematic real-world research exploring the impact of different levels of ISA intervention, ranging from advisory to non-overridable systems. There is little information to date on long-term behavioural adaptation to ISA and even less on long-term adaptation by non-ISA drivers to the presence of ISA vehicles. The implications of different HMIs such as the haptic throttle design used in Sweden and the “dead throttle” approach adopted in the Netherlands and the UK have not been explored. In terms of implementation strategies the full potential benefits of ISA have hardly been touched on: issues that remain to be explored include how best to implement dynamic ISA and what are the implications of the ability, offered by ISA, to provide traffic calming at very low cost. There are also major problems on the system architecture side, which will need to be solved if a pan-European capability is to be offered. And finally, and by no means least, the question of how ISA and non-ISA vehicles can operate side by side has not been addressed.
INTRODUCTION

Twenty years ago, 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, but rather Stupid 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. But the important point is that we now have 20 years of research on ISA to look back on, and so it seems appropriate to carry out a critical review of how fare we have come. Since almost all the research has been carried out in Europe, this paper looks exclusively at the European work. I will attempt to review the findings from all the major studies, covering not only the various field trials but also studies of acceptance, simulation modelling, accident prediction, etc. And I will make this a critical review, since I think it is important to identify where we have made mistakes and where we have failed fully to exploit the research opportunities.

A HISTORICAL OVERVIEW

After the pioneering on-road trial in France in 1982, there was a hiatus in any further real-life tests of ISA for almost ten years. The next trial took place in Lund in 1991–92 and involved two equipped cars which were driven by 75 persons along an 18 km urban test route which had speed limits of both 50 and 70 km/h (Persson, Towlit, Almqvist, Risser and Magdeburg, 1993). The ISA system consisted of a haptic throttle, i.e. of pedal which resisted pressure by the driver’s foot when the speed limit was reached. The speed limit was set by the in-vehicle observer, so this was the first study in which the ISA was “automated” as far as the driver was concerned. Each subject drove the route three times and one-third of the drives were with the speed limiter switched on. The speed limiter not surprisingly produced greater adherence to the speed limit, but there were compensatory effects such as driving faster through intersections and some slight negative effects in terms interaction with other traffic participants.

Since that time, ISA studies in Europe have been virtually continuous. A further study was conducted in Sweden in 1992 as part of Swedish National Road Administration’s ARENA programme in the Gothenburg area (Almqvist and Towlit, 1993). Here roadside transponders to transmit speed limit and other information were placed along a 35 km route around Lake Aspen. The route was mainly rural, but incorporated a number of villages and speed limits varying from 30km/h to 110 km/h. The system had an information-only mode and a mode in which speed limit was set automatically. This trial can therefore be considered the first with a truly automated speed limit system, but the system tested was a hybrid of ISA and Adaptive Cruise Control: the vehicle would drive automatically at the set speed unless the driver intervened by applying the brake. But it was exactly this feature that was commented on negatively by the drivers: they felt pressured to drive to fast in the villages and on sharp curves outside the villages.

At the University of Leeds, we began on work on Intelligent Speed Adaptation in 1995, initially concentrating on using our driving simulator to observe driver behaviour with ISA under controlled conditions (Comte and Carsten, 1997). We deliberately created scenarios in which negative behavioural adaptations might be identified. In 1996 we began further simulator trials on ISA in the European MASTER project, comparing ISA to other methods for slowing traffic on the approach to sharp horizontal curves on rural arterial roads and studying behaviour with a number of ISA variants (MASTER, 1999). Also in MASTER, studies of driver behaviour with a single ISA car were carried out in three countries, Sweden,
the Netherlands and Spain. The test route in each case included urban roads, rural roads and a motorway. Surprisingly, the Dutch subjects indicated they were the most frustrated with the ISA system; rather less surprisingly, the Spanish drivers indicated they were the least likely to buy and ISA system, with the Swedish drivers the most likely and the Dutch drivers in between.

In 1997 there started the first major study of ISA funded by a national transport ministry. This was the External Vehicle Speed Control project funded by the UK Department of the Environment, Transport and the Regions (DETR), with the University of Leeds and the Motor Industry Research Association as the contractors (Carsten and Tate, 2000). The 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 and fuel consumption, and finally to predictions of accident 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). The on-road trials in 1998 were conducted on a 67 km route combining urban roads, rural roads and stretch of motorway. For these trials, a single test vehicle was fitted. This vehicle used a “dead” throttle rather than a haptic throttle, i.e. there was no force feedback to the driver, but rather the fuel supply to the engine was modified to prevent speeding. The speed limit information was from a very simple digital road map with GPS providing the vehicle’s location. The system had a look-ahead function so that it could identify an upcoming change in speed limit. Mild braking was applied when a driver was going too fast on approaching a lower speed zone or when the car’s speed increased to more than 10% above the speed limit, for example when going downhill. The system design was such that it could be assured that drivers were in compliance with the limit at virtually all times. Two versions of ISA were fitted: a voluntary system that drivers could switch on and off at will and a mandatory one that was on all the time. Behaviour with both versions of ISA was compared with non-ISA driving. The simulator study in the project also compared mandatory ISA, voluntary ISA and baseline (no ISA driving). It also investigated an additional form of mandatory ISA in which lower speeds were introduced at certain locations in the network. These locations were substandard horizontal curves and pedestrian crossings.

The same year, 1997, saw the first real field trial with ISA. Twenty-five drivers in the Swedish small town of Eslöv near Lund had their cars adapted for ISA and drove with ISA for two months (Almqvist and Nygård, 1997). Eslöv had a speed limit of 50 km/h throughout the urban area, and, for the purpose of the trial, simple radio transmitters were sited on all the approach roads into the town. As in the earlier trial in Lund, the cars used a haptic throttle. The system was automatically engaged within the urban area and automatically disengaged outside, although the drivers had the option of manually engaging the limiter outside Eslöv.

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 6 subjects, so that there were 120 participants in total. An ISA bus was also tested.

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 sophisticated positioning system, akin to navigation system, in which speed limit was encoded as a road attribute and a combination of GPS, dead reckoning 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.

Not to be outdone by the Dutch, let alone the Danes, the Swedish National Road Administration went on to fund the largest set of trials with ISA to date, which took place in 2000 to 2001 (Swedish National Road Administration, 2001b and 2002). The study was conducted in four different towns and a total fleet of approximately 4,500 vehicles was equipped. The systems were retro-fitted to individuals’ or fleet vehicles. The overall study design is shown in Table 1.

Table 1: Design of Large-Scale Trials in Sweden

<table>
<thead>
<tr>
<th>Town</th>
<th>Communications</th>
<th>In-Vehicle System</th>
<th>Number of vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Umeå</td>
<td>Roadside beacon</td>
<td>Warning with buzzer</td>
<td>3,642 vehicles including buses</td>
</tr>
<tr>
<td>Borlänge</td>
<td>GPS and digital map</td>
<td>Combination of information to drivers and recording</td>
<td>350 cars</td>
</tr>
<tr>
<td>Lidköping</td>
<td>GPS and digital map</td>
<td>Either information or haptic throttle with kickdown</td>
<td>220 cars</td>
</tr>
<tr>
<td>Lund</td>
<td>GPS and digital map</td>
<td>Haptic throttle with kickdown</td>
<td>290 cars and buses</td>
</tr>
</tbody>
</table>

The Swedish research plan and experimental design are remarkable in a number of respects. The trials are very impressive in terms of size. But the study design means that, except in Lidköping, it is not possible to compare the effects of information/warning ISA with intervening ISA, since they were not implemented on the same road networks, and, as far as I know, drivers were not matched between the four study sites. And Lidköping is more of a demonstration than a real trial, since it was conducted by the municipality with no research partner and since the study is focused on acceptance rather than behaviour. Finally, there is no commonality on the data being collected between the different towns: the largest trial, that in Umeå is using roadside data collection, while the other trials have on-board data collection. Thus the opportunity for a detailed evaluation of the effects of different levels of ISA has been to some extent wasted.
Exactly that kind of side-by-side comparison was made in a recent on-road experiment in Finland (Päätalo, Peitola and Kallio, 2001). A test vehicle was equipped with three types of ISA, an information-only system, a mandatory (haptic throttle) ISA and a recording ISA which noted speed infractions. The system was GPS-based and the test route was 17.8 km long and included roads with speed limits of 40, 60, 70 and 80 km/h. The study used a within-subjects design, i.e. all of the 24 subjects drove with each of the ISA variants as well as with no ISA. The most effective system was the mandatory ISA, but the drivers preferred the information-only system.

The latest projects to start are in the UK and (it is rumoured) France, each funded by the respective ministries. The new UK project began in January 2001 and has a duration of over four years. Once again the partners are the University of Leeds and MIRA. The major focus of the project is on long-term behaviour with ISA. Twenty identical modified vehicles will be used in the trials. They will be equipped with a voluntary ISA, which will default to “on”, but which can be disengaged by the driver. The vehicles will also have a kickdown override of ISA. Four successive trials of six months each are planned, with the first two in Leeds and the second two in the Midlands. Like the Aalborg vehicles, a full navigation-type technology applying data fusion will be used to determine location. The road map will have speed encoded as a link attribute and will cover the full local area (in the case of Leeds that is approximately 600 km²) as well as the major national road network. Half of the trials will be with private motorists and the other half with fleets. Other aspects of project work will be a study of overtaking behaviour with ISA in the Leeds driving simulator, and the equipping of a motorcycle and a large truck demonstrator. At the end of the project, the costs and benefits of ISA will be revisited.

The details of the French project are as yet unclear. It is likely that, as in the UK project, trials with twenty ISA vehicles will be conducted. The expansion of ISA research to France is highly significant in that it represents the first extension of ISA research beyond the “safety ghetto” of northern Europe. A project in Belgium is also on the cards.

Over the period of twenty years ISA 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, 2001a). In other words ISA has grown up. 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.

Another point worth making is that there has been no technology push with ISA. ISA has been an application looking for technologies to deliver it. Those technologies are now mature enough that a reliable low-cost ISA is feasible. And unlike other in-vehicle systems, there has been a relatively small contribution from European Commission research. Here there is a major contrast between ISA and other advanced driver assistance systems such as those discussed in Zwaneveld et al. (1999).

RESULTS OF FIELD TRIALS AND BEHAVIOURAL STUDIES

From the above review of the major projects to date, it is clear that the major focus of those projects has been on-road trials with ISA. Not surprisingly, given the considerable effort expended in conducting those trials, some useful findings have been obtained. One finding is that ISA works, not just from a technical point of view but from a behavioural point of view. With ISA, particularly with intervening forms of ISA where the system is linked to vehicle control, drivers who would otherwise tend to speed are restrained from speeding.
And that restraint results in observable improvements in safety. Thus in the Lund trial of 1991–92, the subjects had 0.23 conflicts per drive when driving without ISA, but 0 conflicts per drive when driving with ISA (Persson, Towlial, Almqvist, Risser and Magdeburg, 1993). In the Eslöv trial, two conflicts were observed without the speed limiter and none with the limiter (Almqvist and Nygårård, 1997). In the UK on-road trials in the External Vehicle Speed Control project, critical events and conflicts were significantly lower than in the initial non-ISA drive with either form of ISA, but increased over successive drives without ISA (Comte, 1999).

These of course are important findings, but on their own they hardly justify the huge investment in research on ISA. It is perhaps a great pity that there has been rather little systematic comparison of behaviour with variants of ISA. The data on ISA usage collected in the UK External Vehicle Speed Control project revealed that drivers using the ISA in voluntary mode were highly manipulative: they tended to keep ISA on in congested traffic when the system would have no effect, but they tended to switch it off when the road ahead was clear and they had then opportunity to speed (Comte, 1999). Such results would tend to indicate that the safety benefits of a voluntary ISA would be rather lower than the overall usage rates might indicate.

Perhaps the paucity of results compared with the large effort expended is related to the aims of the trials. It is certainly the case that many of the trials have not had the study of behaviour as their major focus. The Dutch Ministry was explicit here:

The primary goal of this practical study was to examine whether ISA is a realistic option as an instrument for speed control, both from a technical-operational and from a social point of view. A major evaluation objective was to measure public acceptance of this type of ISA application, both with test drivers and with the general public...[A] main objective, therefore, is to demonstrate, in actual practice, that ISA as an instrument for speed control is a viable option in the Netherlands. (Besseling and van Boxtel, no date)

In other words, the primary goals of the Tilburg trial were to test the technologies and to promote ISA. The second goal, that of promotion, could potentially be in conflict with a requirement for objective analysis of behaviour.

Equally, the recent large-scale trials in Sweden seem to have been as much if not more about promoting ISA than about studying ISA. The primary focus has been on attitudes. Thus Torbjörn Biding, the manager of the overall project, described the plans as follows at the beginning of the project:

“Our reasons for choosing cities of various sizes from north to south is so that we can see how ISA works in different traffic cultures. The local climate, traffic situation and drivers’ needs are some of the things that differ between the four cities and which most probably will affect how widely accepted ISA will be.” (Swedish National Road Administration, 2000)

The same newsletter lists the objectives of the evaluation as follows: first, user attitudes; second, the integration of the technology in the vehicles; and third, the effect on road safety and the environment.

There is a real danger here that the various objectives may interfere with each other. Promotion of ISA and objective study of ISA may not be compatible. At the very least, it is
incumbent on those who carry out studies where promotion is combined with behavioural analysis to show that the promotion effect can be taken into account. One way to do this would be to have different groups of subjects some of whom are subjected to no promotional activities and some of whom undergo one or other form of persuasion. The Dutch trial in Tilburg was planned as the precursor to a much larger follow-on study. It was always intended to focus on reliability and acceptance with the behavioural evaluation as an added bonus. So here the potential contamination of the behavioural data is excusable. But in the case of the Swedish trials, the excuse is far less. To spend 75 million crowns (approximately 9 million euros) on trials, without a scientifically-based experimental design and with only incomplete behavioural data, seems criminally wasteful.

**ISA TECHNOLOGIES**

There is general agreement now on a system architecture for ISA. The basic system being adopted virtually everywhere is the autonomous one that uses navigation-type technology to determine the road a vehicle is on. A combination of GPS, compass reading, gyro information and map matching is used to select the most probable road and hence identify the appropriate speed limit. There is very reason to believe that such a system can work reliably, but we do not know that it works reliably. Although it has been a major aim of many of the ISA trials to show that the technology works, it is not possible to determine from the published results how well it works. How often does the integrated positioning system fail and in what circumstances? How crucial is the GPS? How quickly does the system recover after an error or a failure? How often is the vehicle or driver given the wrong speed limit information? None of this can be ascertained from the published literature. Do we conclude that the results have not been collected or that they are too negative to publish?

If there is agreement on how to provide speed limit information, there is much less agreement on the human machine interface (HMI). From the very beginning, the Swedes have favoured the haptic throttle which gives force feedback to the driver as the way to discourage or prevent speeding in an intervening ISA. In the UK, from the beginning of our work, we have favoured the “dead throttle”, which simply ignores a driver request for further acceleration beyond the speed limit. The Tilburg trial used a similar HMI. In the UK, we have also provided a mild braking capability to the ISA. With this braking capability, it is possible to preclude virtually any opportunity to speed. But there has been no side-by-side comparison of the two overall interface designs, either in terms of user preference or in terms of effectiveness. So in saying that one is better than the other, we speak from conviction rather than from scientific knowledge.

**ACCEPTANCE**

Attitudes towards ISA are clearly an important issue. Without public acceptance, ISA will not be widely adopted and no government will take the decision to require ISA without strong public support. There are some indications that substantial support is already there: a recent opinion poll in the UK found that 53% of driving licence holders favoured fitment of mandatory ISA. But such attitudes may not be very deeply held and we need to know how those attitudes will be influenced by experience of ISA in a long-term trial.

As already indicated, attitudinal studies have been a major component of research on ISA; indeed in many trials attitudes have been the primary focus. The study of 1991–92 in Lund
found that drivers were more positive about the benefits of mandatory speed limiters when they had just driven in the ISA car (Persson et al., 1993). Subsequent studies have tended to confirm this increase in positive attitudes: in the Eslöv trial, 73% of participants rated themselves as more positive about ISA after using it (Almqvist and Nygård, 1997). They indicated a strong preference for the feedback from the haptic throttle over warnings by buzzers or lights.

In the on-road trials in the External Vehicle Speed Control project, we also found indications of more positive attitudes after using ISA. Subjects rated the mandatory system as more “useful” after experiencing it as compared with their prior conception, and they also rated it less negatively in terms of “satisfaction”, although they were still quite negative about it in this respect (Comte, 1999). It also has to be conceded that the drivers who drove with the voluntary system were much more positive about their experiences than the ones who drove with the mandatory system.

But some of the attitudinal work on ISA can be criticised for not being sufficiently rigorous. There has, I believe, sometimes been a tendency to ask questions in a leading manner in order to elicit the wished-for answers. A survey on attitudes concerning speed and countermeasures to excess speed was conducted in the MASTER project (Risser and Lehner, 1998). One question was as follows:

“How do you feel about driving with high speed yourself?”

The respondents had to agree or disagree on a five-point scale with the following statements:

Speed:
- is dangerous
- is exciting
- gives a feeling of freedom
- helps to save time
- makes one look dynamic
- shows that one can handle the vehicle
- is reckless
- is aggressive

Only one of these sub-questions, the one about saving time, is not emotionally laden. I imagine that the respondents could easily ascertain what was the “correct” end of the scale.

Now I do not wish to say that such studies cannot uncover important attitudinal issues or differences in attitudes between groups. Indeed this very study revealed significant differences in attitudes about speed between drivers and pedestrians. But I think it is incumbent on researchers to design questionnaires in such a way that they are as neutral as possible.

SAFETY PREDICTION

Everyone would like to know how many accidents ISA would save. Improved traffic safety is the primary purpose of ISA, and any policy-maker taking a decision on whether and how to move ahead with ISA, would wish to know the predicted size of the safety improvement. That same quantity or set of quantities (for different types of ISA will produce different accident savings), is obviously crucial for making a cost-benefit analysis and for comparing ISA with alternative implementations and investments.
The earliest safety prediction for ISA that I have been able to find is that made by Malaterre and Fontaine in 1992 (cited in Hydén, 1994). Actually this was not strictly for ISA but rather for an Intelligent Cruise Control combined with speed limit information obtained from roadside transponders. The system envisaged was what we in the UK have termed a “variable” system: in addition to transponders at speed limit signs, it would also incorporate transponders at sharp bends and around zebra crossings. Two modes to the system were considered: an information only mode and an automatic mode. The source of information for the accident prediction was a medium depth accident database containing a 2% sample of accidents, and the method was presumably an expert review of those accidents. The predicted savings in injury accidents was 2.8% for the informative mode and 17.5% for the automatic mode.

A somewhat similar approach was adopted by Perrett and Stevens (1996) in making predictions for accident savings in the UK with ISA. They identified a subgroup of accidents as being speed-related, i.e. those accidents in which at least one participant was identified as driving too fast for the situation. They concluded that a full dynamic ISA, in other words a system able to adapt speed limits to prevailing conditions, could save a maximum of 16% of injury accidents and that a fixed ISA, in other words one incorporating the posted speed limits, could save 8% of injury accidents.

More recent studies have adopted an alternative approach, namely to see all accidents as potentially speed related and to use for safety prediction one or more of the empirically derived relationships between speed and accidents. Using this approach, Várhelyi (1996) predicted that a fixed ISA system would save 15% of the injury accidents in Sweden and that a dynamic system would save between 19% and 34%. This latter calculation was affected by a group of accidents whose circumstances were unspecified. If those accidents were excluded from the calculation, then dynamic ISA was predicted to save between 24% and 42% of injury accidents.

The estimation of accident savings that we made for the UK produced comparable numbers (Carsten and Tate, 2000; Carsten and Tate, 2001). They are shown in
Table 2. We envisaged a number of ISA variants. In terms of intervention level, we had three types: an advisory ISA not linked to vehicle controls; a "Driver Select" ISA, with which the driver could turn on and off the link to the vehicle controls; and a mandatory ISA with no disengagement possibility. Speed limits could be as now (i.e. the roadside posted speed limits; they could be geographically variable with lower limits at certain locations such as sharp curves or around pedestrian crossings; or, in addition to the variable function, they could be dynamic, so that they changed in response to current weather and traffic conditions. The prediction is that the most powerful and versatile form of ISA, the Mandatory Dynamic system, will reduce injury accidents by 36%, fatal and serious accidents by 48% and fatal accidents by 59%. The scenario here, as in Várhelyi (1996), is an immediate introduction of ISA into the vehicle fleet and 100% fitment achieved overnight.
Table 2: Best Estimates of Accident Savings by ISA Type and Accident Severity

| System Type | Speed Limit Type | Best Estimate of Injury Accident Reduction | Best Estimate of Fatal and Serious Accident Reduction | Best Estimate of Fatal Accident Reduction |
|-------------|------------------|-------------------------------------------|==================================================|===================================|
| Advisory    | Fixed            | 10%                                       | 14%                                               | 18%                                |
|             | Variable         | 10%                                       | 14%                                               | 19%                                |
|             | Dynamic          | 13%                                       | 18%                                               | 24%                                |
| Driver Select (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%                                |

These predictions of the safety effect of ISA have one deficiency in common: they assume that, apart from the change in speed induced by ISA, there are no additional behavioural effects. In other words, they assume no behavioural adaptation to ISA. But we know from observations of driver behaviour, particularly those conducted in our driving simulator at Leeds, that it is erroneous to assume that behaviour with ISA is the same as behaviour without ISA. In a number of studies, we have observed adaptational effects of ISA at least in the short term (Comte, 2000). We have found that drivers with ISA tend to adopt shorter headways in car following, and to adopt smaller gaps in interaction with other vehicles at junctions. Another adaptational effect observed in many of the on-road trials is that drivers without ISA tend to engage in “pushing” (very close following) of an ISA car (e.g. Persson et al., 1993). Whether these effects persist with long-term acclimatisation to ISA is currently not known.

It is not possible to adjust the safety predictions for ISA to take account of such adaptational effects — at least it is not possible to do so in a scientific way. But it is theoretically possible to do so in a microsimulation model which incorporates unsafe behaviours and which measures near-accidents or conflicts. This is the approach adopted by Archer and Åberg (2000) in their modelling of the safety impact of an advisory ISA. But as yet, their work is only at a preliminary stage and the behaviour of drivers in the model has not been calibrated to that observed in field trials with ISA. Nevertheless, they have pointed to some interesting effects, particularly that speed variance may be increased at low levels of system penetration, resulting in a net increase in conflicts as compared with the non-ISA situation.
AN ISA RESEARCH AGENDA

Based on this review, it is possible to identify a considerable number of ISA research themes that remain relatively unexplored. I will briefly summarise the ones that have occurred to me.

The first, and one of the most important, is the one where there was a missed opportunity in the large-scale Swedish trials. That topic is a systematic investigation of the impact of different levels of ISA intervention, ranging from information, through warning, to voluntary control and then to various levels of intervening system and finally to non-overridable systems, on driver behaviour and traffic safety.

We should be looking not just at short-term behavioural response, but at long-term changes. Do the negative behavioural adaptations to ISA that have been observed in a number of studies persist with longer acclimatisation to ISA? Or do drivers stop fighting the system and become more accepting of the small delays that may arise?

This leads on to the adaptation by non-ISA drivers to the presence of ISA vehicles. Do they too begin to accept, with increasing familiarity, that the car in front may have ISA and that the driver in front may not be willing or able to speed up even when pressured to do so.

In terms of ISA design, we need to study the implications of different HMI's such as the haptic throttle design used in Sweden and the "dead throttle" approach adopted in the Netherlands and the UK. Which do users prefer? Which produces the greatest amount of speed compliance?

Again in terms of system design, we have not even begun to tackle the decision rules for dynamic ISA. How much speed reduction is needed in fog to make driving under reduced visibility no more dangerous than driving in normal visibility? How far upstream from an incident do we need to slow traffic? How do we ensure that the limits are not changed every few seconds by an automated decision centre?

If we decide on the decision rules, what should be the system architecture side for a pan-European capability, including for dynamic ISA? How can we broadcast speed messages to vehicles and how can we ensure that those messages are received?

In all these system design aspects, we need to work with standards bodies worldwide. Compatibility between ISA and other Intelligent Transport Systems needs to be ensured.

In terms of the benefits of ISA, we have only scratched the surface. ISA offers the possibility of traffic calming at virtually no cost. It also offers the possibility of new approach to blackspot treatment. In the UK, as in many other European countries we have severe problem with accidents at junctions on high-speed rural roads. These accidents involve traffic crossing and entering from the side road, and traffic slowing or stopping to turn off the main road. The standards solution to these accidents is very expensive reconstruction of the junction, sometimes to the extent of building a full interchange. ISA offers the possibility of a low-cost, but equally effective solution in the form of slowing traffic on the main road. These and other possibilities need to be explored and quantified.

The Germans, in particular, have claimed that there are legal problems with ISA. They assert that mandatory ISA would be breach of the Vienna Convention on driving which stipulates that the driver has responsibility for speed choice. This argument is clearly spurious — the Vienna Convention does not prevent heavy truck or intercity coaches from being fitted with speed limiters. But we still need to explore a legal framework for ISA. Would ISA require some kind of on-board data recorder so that it would be possible to
ascertain whether a vehicle had received a dynamic message to slow down in fog? Can a country require tourist traffic to have the same ISA functionality as native vehicles?

And last but not least we need dialogue and communication with the public. We need thorough studies of acceptance, but we also need to discover the most effective ways to encourage voluntary take-up of ISA, whether by fleets or by individuals. And we need to prepare a communication strategy for the battle royal which is bound to occur when the safety community proposes to move ahead with mandatory ISA.

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