isa - UK

intelligent speed adaptation

Executive Summary of Project Results

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1 What is Intelligent Speed Adaptation (ISA)?

This is a system in which the vehicle “knows” the speed limit. That knowledge can be used to display the current speed limit to the driver and to provide warnings when the vehicle is exceeding the speed limit. The information can also be linked the vehicle engine management system and, if desired the brakes, so as to keep the vehicle below the speed limit when the limit is known. An override to allow the driver to exceed the limit when desired can be provided.

The technology behind ISA is typically the use of an enhanced navigation system, which in addition to all the typical information about road layout and features also incorporates speed limit as a road attribute. There is no need for a driver to enter journey start point or end point into the system; rather the ISA system automatically detects the road on which the vehicle is travelling and hence the speed limit. A special display is provided to show the current speed limit and system status.

ISA can take various forms:

- In terms of intervention level, it can be advisory (the driver is informed of the limit and of violations), voluntary (the system is linked to the vehicle controls but the driver can choose when to have the system enabled), or mandatory (no override is possible).
- The speed limit information can potentially be extended to incorporate lower speeds at certain locations in the network and even in the future variation with current network conditions, based on weather, traffic density, the presence of incidents, etc.

In this project, the major research focus was on driver behaviour and safety with a voluntary (i.e. overridable) ISA system which featured information on the normal, static speed limits.

2 Objectives of the Project

The main tasks of the Intelligent Speed Adaptation project were to:

- Investigate how car drivers behaved when driving with ISA by means of set of field trials with a voluntary ISA
- Study overtaking behaviour with ISA in a driving simulator
- Prepare an ISA design for motorcycles and large trucks and to build a demonstrator of each
- Investigate the costs and benefits of ISA

There were a number of core issues to be investigated:

1. How would behaviour change over the long term when driving with ISA?
2. How would user attitudes change with long term exposure to ISA?
3. Would compliance with a voluntary ISA vary by type of road and type of driver?
4. Would some manoeuvres become more dangerous with non-overridable ISA and what would be the implications if they did?
5. What practical issues would be raised by the application of ISA to other motor vehicles, such as trucks and motorcycles?
6. Would truck drivers and motorcycle riders react differently to ISA?

The most substantial part of the project work was the field trials looking at the long-term behaviour of car drivers with ISA. These trials allowed comparison of:

- Driving with ISA with driving in the pre (non-ISA) situation
- Driving with ISA with driving in the post (after-ISA) situation
- Driving in the pre situation with driving in the post situation (both non-ISA) to investigate whether their experience of an ISA influenced subsequent driving.

This Executive Summary is based on a considerably longer Final Report. That Final Report in turn summarises a series of more detailed technical reports which are publicly available.

3 Car Trials

3.1 Introduction

The objective of the car trials was to investigate how drivers would behave in everyday driving with a car equipped with voluntary ISA. The major focus was naturally on their speed choice — would ISA reduce the amount of speeding and if so by how much, and would it affect their speed choice across the range of speeds or only in terms of curtailing excess speed (i.e. speeds above the limit). Other issues were:

- What would be the acceptance of ISA?
- How would the experience of driving with ISA affect driver attitudes?
- When and where would drivers choose to override the voluntary ISA?
- Would behaviour with an attitudes to ISA vary by type of driver?
- Would compliance with ISA vary by type of road?
- How would drivers assess the impact of ISA on the quality of their driving?

A fleet of twenty cars was converted to provide ISA support, and these vehicles were used in four successive field trials. The participants in the trials drove the converted car on a daily basis for six months; the first month driving without ISA, the next four months driving with ISA, and the final month driving without ISA once again. The first month of driving served as a baseline for comparison with the ISA activated period, and the final month of driving provided the opportunity to identify any impact of experience with ISA on subsequent driving.

The four trials were:

Trial 1: Leeds area with private motorists

Trial 2: Leeds area with fleet motorists

Trial 3: Leicestershire with private motorists

Trial 4: Leicestershire with fleet motorists

The Leeds trial was in a major urban area, although the speed limit data covered the whole of the Leeds Metropolitan District, which includes some outlying rural areas and villages. The Leicestershire area was mainly rural and small-town.

3.2 Method

The vehicles

The ISA system was installed on a fleet of 20 Skoda Fabia Elegance 1.4 litre estate (see Figure 1). The system used two computers concealed below the rear floor of each vehicle. One of the two computers provided the information function, i.e. vehicle position and current speed limit, and the other provided speed limiting and data recording. There were also additional hardware elements wired to the vehicle's fuel and brake systems, the instrument panel, and the steering wheel. The appearance of the ISA vehicles was much as an ordinary Skoda Fabia. The speed limit map installed on one of the computers in the vehicle's boot provided essential information for the ISA system to function correctly.

Figure 1: One of the ISA vehicles

The intention was to integrate the ISA system into the vehicles so that it would appear to the users as though it was original equipment. There was no visible wiring and the controls required were concealed behind the glove box and next to the spare wheel well under the rear floor.

The position of the accelerator pedal demand (i.e. driver speed demand) was determined by an electronic sensor unit. The ISA control system compared this speed demand with the permitted maximum speed, i.e. the speed limit. Under ISA speed limiting, any demand by the driver for a speed in excess of the limit was ignored. The driver could override this limiting either by pressing the red button on the steering wheel or by depressing the accelerator pedal fully so as to make contact with an actuator button. Speed limiting would be resumed when the driver brought vehicle speed back below the limit *or* when the driver pressed the reengage (opt-in) button on the steering wheel *or* when the vehicle entered a new speed limit zone.

In addition to control by throttle, the ISA system could apply mild braking so as to try to keep the vehicle within the speed limit, for example when going downhill. This was done by means of an actuator fitted to the brake pedal.

In order to discourage "over-throttling" (i.e. the driver flooring the accelerator pedal), the ISA system would activate a vibrating motor fitted to the accelerator pedal in situations where the driver was depressing the accelerator excessively. This gave the driver tactile feedback and encouraged him or her to press less hard.

In the four-month period of driving with ISA, the LCD screen displayed the current speed limit when known. If the ISA system was engaged then the speed limit was shown within a circle; when the system was overridden by the driver the circle would be removed. Any change in system state was signalled to the driver by means of a "beep" as well as being displayed.

Participants

Participants for the field trials with private motorists were recruited in response to adverts placed in local newspapers. Participants for the fleet trials were recruited from local organisations — in Leeds from employees of Leeds City Council (LCC), and in Leicestershire from various local authorities as well as a private company Because one participant had to withdraw during the fourth trial, complete data were only collected for 79 participants.

Table 1: Characteristics of participants

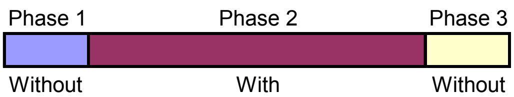
Gender	Age	Intention to Speed	Number
Male	23–39	Intender	11
Male	23–39	Non-Intender	8
Male	40–60	Intender	13
Male	40–60	Non-Intender	12
Female	23–39	Intender	6
Female	23–39	Non-Intender	11
Female	40–60	Intender	11
Female	40–60	Non-Intender	7

Within each trial the aim was to balance the number of participants equally across various driver characteristics: male/female, young (25–40) or old (41–60), and intender/non-intender (based on prior intention to speed as defined by an attitudinal questionnaire). It proved impossible to recruit the intended balance of driver across all the trials. Therefore the final combination of participants was as shown in Table 1.

3.3 Results

Behavioural results

As stated earlier, each trial was divided into three phases, as shown below:



Phase 1 was one month with no ISA, to serve as the baseline;
Phase 2 was four months with the ISA system active;
Phase 3 was one month with the ISA once more inactive, for the study of carry-over effects.

The analysis examined speed choice and the propensity to speed by road category, with road category being defined as speed limit. ISA had an impact on the amount of speeding across all speed limits. The only exception was 60 mph roads where, in line with national observations of traffic speeds, there was very little speeding in the before-ISA phase. The typical pattern was for speeding to reduce in Phase 2 as compared to Phase 1, and then for there to be at least a partial return to the baseline behaviour in Phase 3, resulting in the V-shaped pattern which can be seen in Figure 2. This figure shows mean speed within each trial phase. The effect of ISA on speed choice can be observed even more clearly from Figure 3 which shows 85th percentile speed, i.e. the speed below which 85% of the distance travelled was covered. ISA affected high-end speeds much more than it affected average speeds.

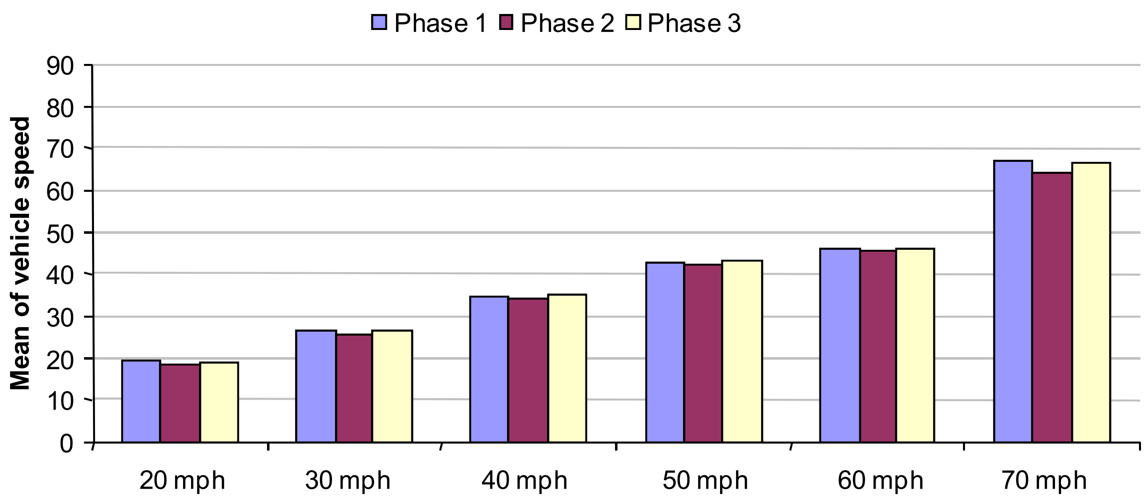


Figure 2: Comparison of mean speed across trial phases

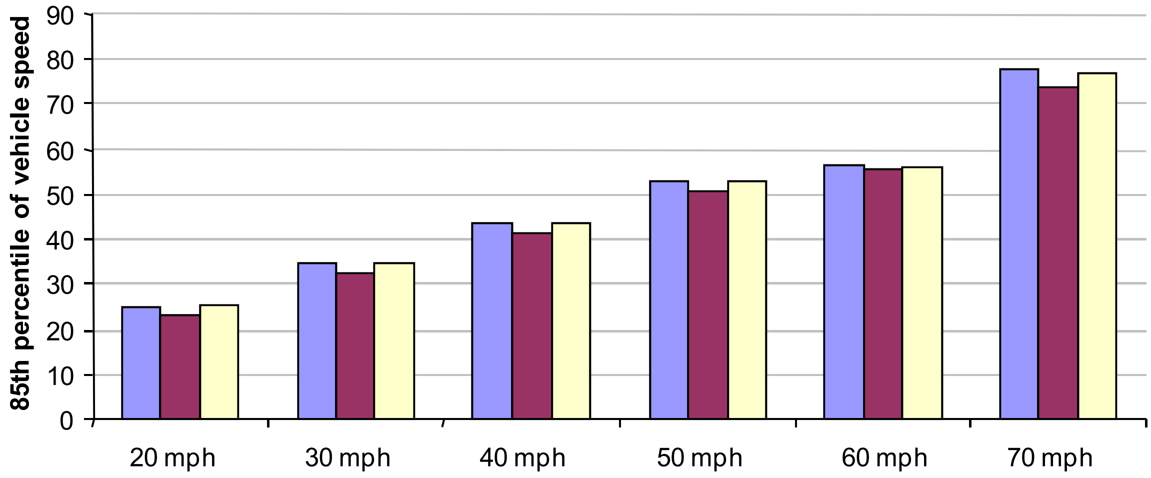


Figure 3: Comparison of 85th percentile speed across trial phases

The impact of ISA was even more pronounced when looking at the relative amount of speeding in the three phases, as shown in Figure 4. With ISA, there was a reduction in the proportion of distance travelled over the speed limit for all speed limits apart from 20 mph. This reduction was smaller on 60 mph roads. However, the impact of ISA did not generally carry over to driving in Phase 3.

It is also clear that ISA did not eliminate speeding.. This was in part because the drivers could override the ISA system and they chose to do so to a lesser or greater extent. But it was also in part due to the design of the ISA control of vehicle top speed. The ISA system did not cut off acceleration sharply at the speed limit. There was some lag in the reaction of the system, drivers could speed somewhat when going downhill and could also speed for a short while after entering a lower speed zone. But ISA did have a very marked effect on very large exceeding of the speed limit. This can be observed when examining more detailed plots of speed choice.

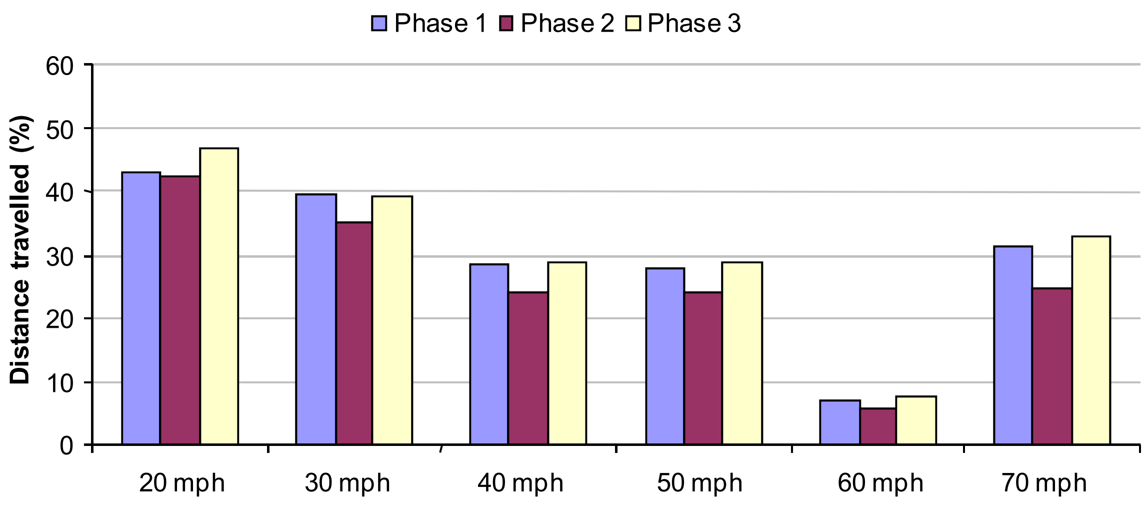


Figure 4: Comparison of percentage of distance travelled over speed limit across trial phases

Such plots are shown in Figure 5 and Figure 6. In each of the plots the proportion of distance travelled within each phase of the trials is shown for 5 mph speed ranges. From Figure 5, for 30 mph roads, it can be seen that ISA had no impact on the speed of driving at the lower end. However, it had a very pronounced effect on speeds at the top end. Driving with ISA also produced a bulge in the distribution just below and just above the limit. A very similar impact can be seen in Figure 6 for 70 mph roads, i.e. motorways and high-speed dual carriageways. Here there are even some signs that the impact of ISA, in terms of curtailing very high speeds, persisted after the ISA system was switched off.

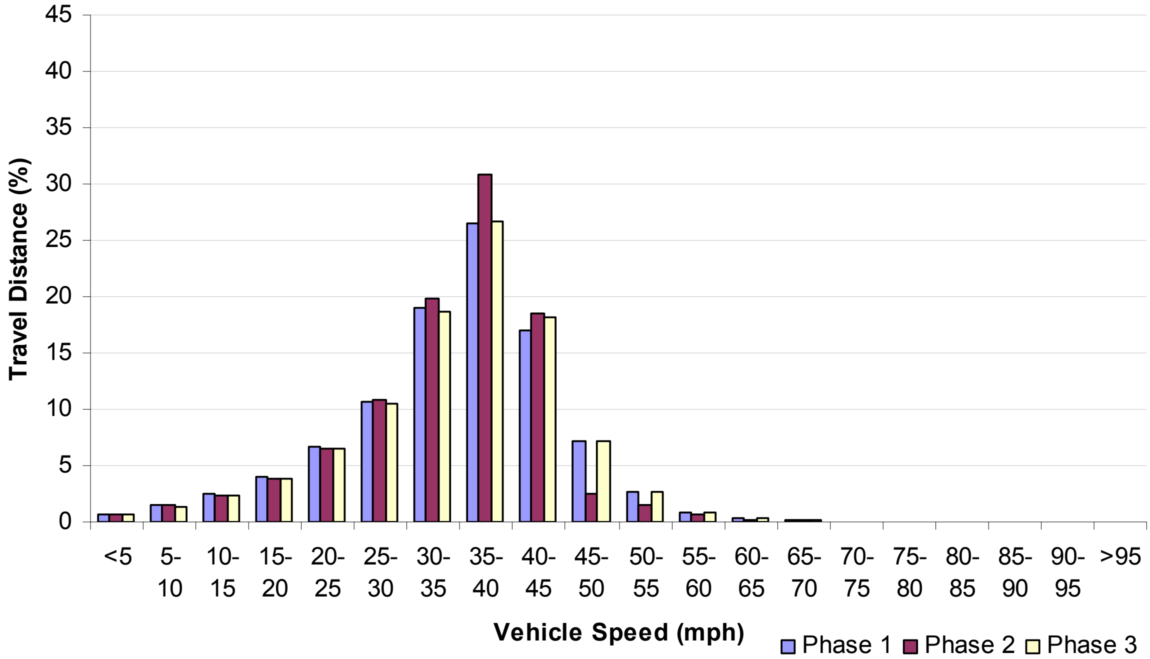


Figure 5: Speed distribution by phase on 30 mph roads

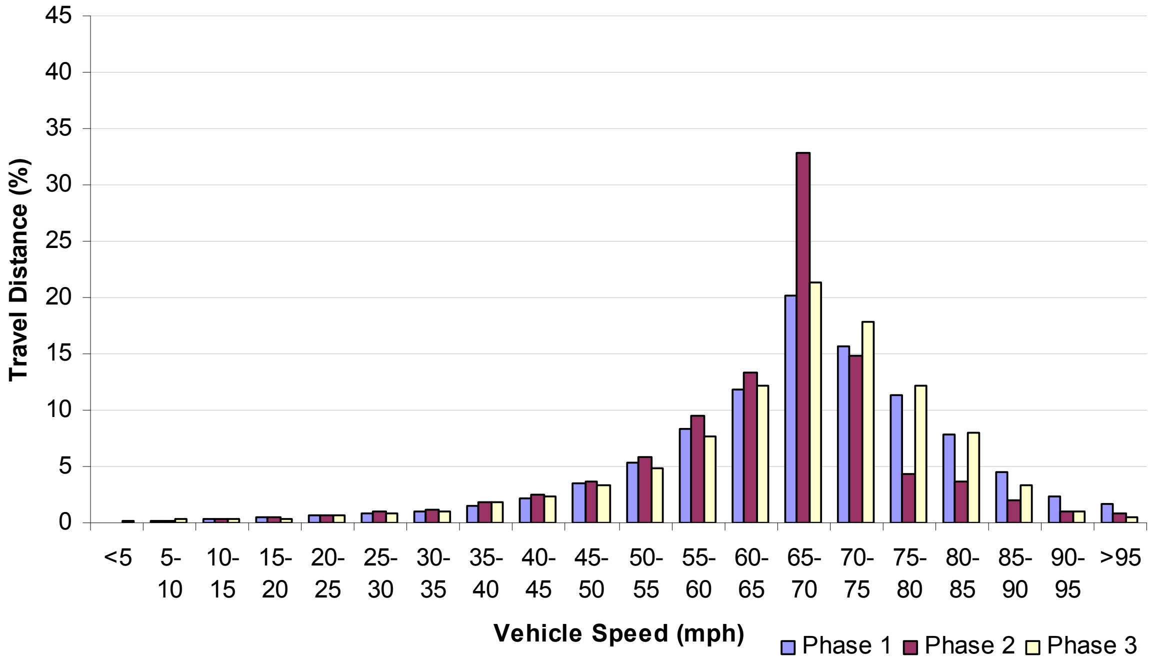


Figure 6: Speed distribution by phase on 70 mph roads

The use of an voluntary ISA system also provides an opportunity to examine where drivers were willing to accept the control of the ISA system and where they chose to override it. The proportion of distance travelled with ISA overridden was highest on 70 mph roads (see Figure 7).

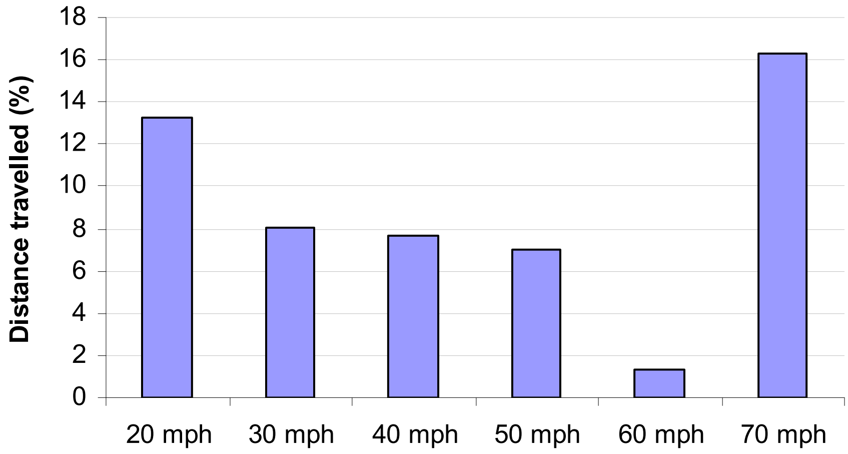


Figure 7: Proportion of distance travelled with ISA when the system was overridden

Overriding behaviour can also be examined by driver group. In general, young drivers overrode more than older drivers, males more than females, intenders to speed more than non-intenders and the private motorists slightly more than the fleet drivers (see Figure 8).

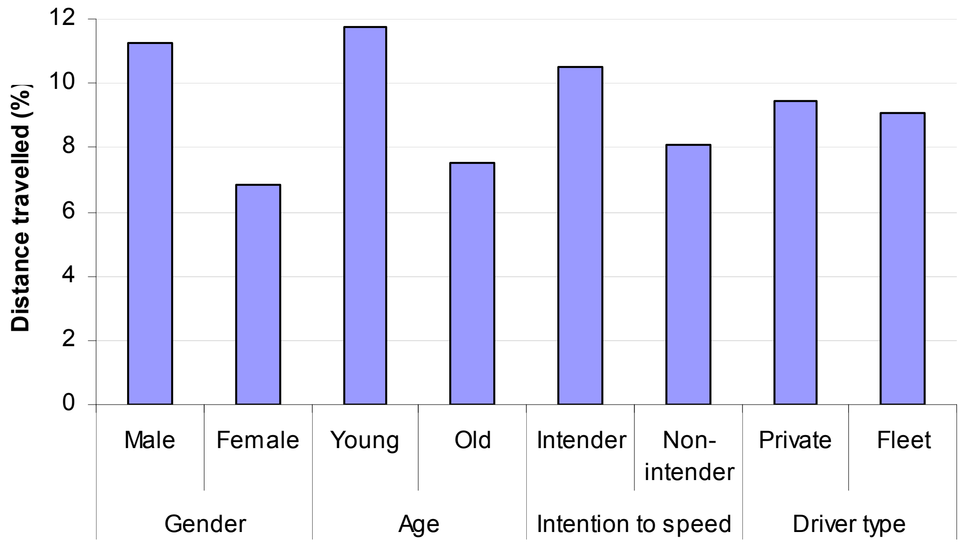


Figure 8: Comparison of overall overriding behaviour across driver groups

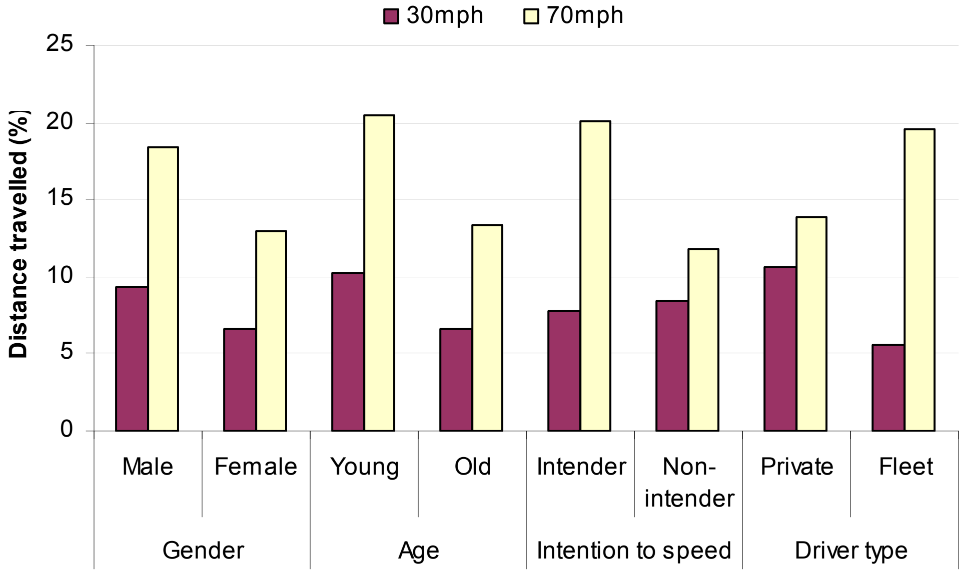


Figure 9: Comparison of overriding behaviour on 30 and 70 mph roads across driver groups

Figure 9 examines the propensity to drive with ISA overridden on 30 mph and 70 mph roads. It can be seen that the patterns by gender and age were the same for the two road categories. However, speed intenders and non-intenders had similar behaviour on urban roads but behaved differently on 70 mph roads. There was a notable difference in behaviour between the private motorists and the fleet drivers: private motorists overrode more frequently than fleet drivers on urban roads, while fleet drivers overrode more frequently than private motorists on 70 mph roads. This suggests that the fleet drivers may have been more conscious of the need to comply with the speed limits on urban roads, but felt less compunction about speeding on 70 mph roads.

Attitudinal results

Driver attitudes to speeding and ISA were assessed systematically at various points during the trials. Figure 8 shows the change over time for intention to speed. It appears that the experience of driving with ISA reduced drivers' intention to speed. Intention was lowest right at the end of the trial, when the drivers had been driving without ISA for their final month. An additional result from the attitudinal questionnaires was that, following experience with ISA, participants were less likely to believe that speeding would get them to their destination more quickly. Thus they seem to have become aware that ISA did not have a drastic effect on journey time. On the other hand, in terms of the belief that "*speeding would make me feel good*" participants were

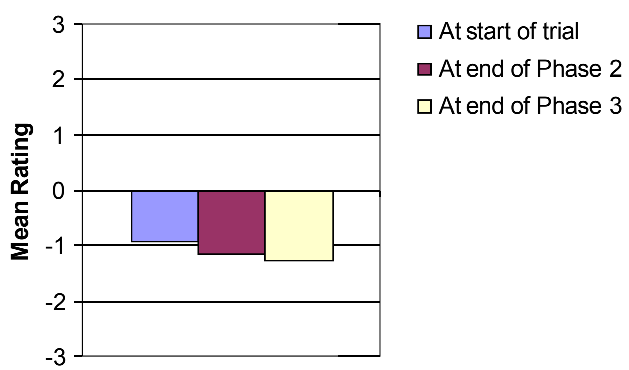


Figure 10: Mean intention to speed

more likely to believe that speeding would make them feel good following experience with the ISA system. So ISA did not reduce the enjoyment of speeding — on the contrary there was evidence that this increased.

Various questionnaire were administered to determine changes in the acceptability of ISA, in attitudes towards the ISA system and in workload experienced when driving with ISA. This set of questionnaires was administered at four time points:

Time 1: at initial vehicle handover,

Time 2: following one month of ISA activation,

Time 3: following four months of ISA activation, and

Time 4: following the one-month return to non-ISA driving.

The Driver Behaviour Questionnaire (DBQ), which is a commonly used tool to investigate driver errors, was used to measure self-reported aberrant driving. The results are shown in Figure 11. All three types of aberrant behaviour — lapses, errors and violations — declined over time and continued to decline after ISA was removed. Thus experience with ISA apparently reduced all error types, including the violations, which are the most serious.

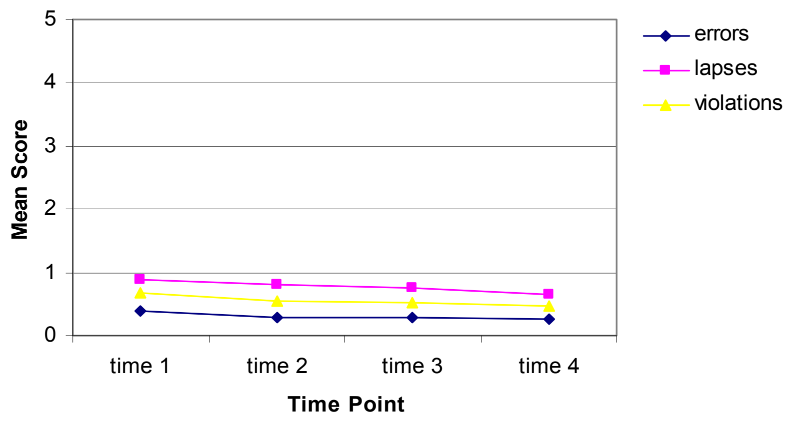


Figure 11: Mean error, lapse and violation scores on DBQ over time

Driver acceptance of the ISA system was measured using an acceptability questionnaire which measures usefulness (how good is it for the traffic system) and satisfaction (how much does it fulfil my goals). The results are shown in Figure 12. As regards usefulness, there are indications that the early experience with the system decreased participants' appreciation of the usefulness

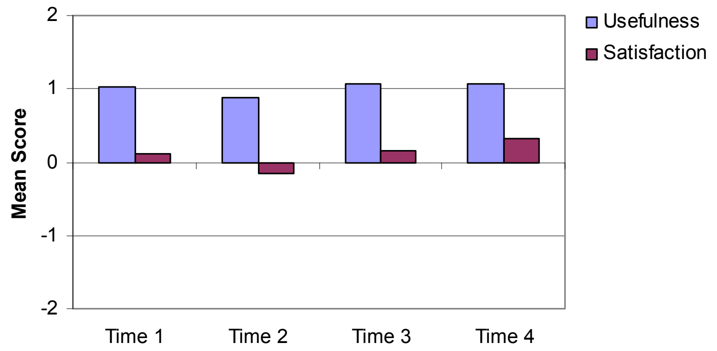


Figure 12: Acceptability rated in terms of usefulness and satisfaction

of ISA as compared with their preconception, but that this appreciation increased with prolonged experience and continued at a high level even when the system was removed. Ratings of satisfaction generally improved over time, following a slight dip at the beginning of driving with ISA. Satisfaction was highest after the removal of ISA support. Speed intenders rated the ISA system as significantly less satisfying than did non-intenders.

Participants' perceptions of risk with ISA were ascertained over time. In the majority of conditions, participants considered driving with ISA safer than driving without the system. However, participants felt at increased risk with ISA when overtaking or driving in fast moving traffic. They also indicated a slight increase in perceived risk when driving on motorways. Thus when wishing to put on a burst of speed or keep up with fast traffic, ISA was seen as slightly problematic. On the other hand, participants' ratings of the quality of their driving generally improved with ISA. They indicated that their anticipation of conflicts, attention to other road users and pedestrians increased when driving with ISA compared to unsupported driving. Perhaps, unsurprisingly, participants' awareness of speed limits also increased when driving with ISA.

In terms of attitudes to the introduction of ISA more widely, 54% of participants would be willing to have ISA installed in their vehicles if its use was voluntary. Participants' willingness to pay for the system ranged from paying nothing to £500. On average participants would be willing to pay £111. Sixty-two percent of participants approved of requiring the fitment of ISA on all new vehicles and 56% approved of compulsory usage of ISA by all drivers.

4 Truck and Motorcycle Trials

4.1 Introduction

The truck and motorcycle trials were aimed at demonstrating that ISA was a system that could be applied successfully to vehicles in very different categories from cars. It was also the intention to assess user response to both truck and motorcycle ISA. But there were substantial differences to the approach adopted to the two types of vehicle. It was relatively straightforward to transpose ISA design to a truck. Thus the major question was the impact of ISA on driver speed choice when driving a truck and on driver attitudes in this environment. Because of motorcycle dynamic behaviour, the application of ISA was a much more substantial design challenge. Therefore the approach adopted was to gather feedback from motorcycle riders through evaluation of ISA in a test track environment.

4.2 Truck trial

The chosen vehicle was a 7.5 tonne MAN TGL 180 rigid truck. This has a driver-set variable speed limiter which could serve as a kind of socket into which the ISA speed limit information system could plug. The system design was very similar to that on the Skoda Fabias. The truck can be seen in Figure 13.

Figure 13: The MAN TGL 180

The interface used in the ISA truck was similar to that implemented in the ISA passenger cars. There was an opt-out button and an emergency disable button located in the central console. The speed limit was shown on a LCD display and changes of speed limit were accompanied by an auditory beep. Overriding of ISA could also be initiated by a kick-through function implemented on the acceleration pedal.

However, there were aspects of the ISA truck interface which were different from the cars. For example, the accelerator pedal did not vibrate. This was because most commercial vehicle drivers wear safety boots with thick soles and it would therefore be unlikely for the driver to feel vibration through the pedal. However, there were no technical difficulties that prevented the addition of this feature.

In addition, engine braking was used instead of the service brake in the ISA truck. This design decision was taken as the braking system on the truck had a more aggressive initial retardation force than the system on the ISA passenger cars. It was considered that utilising engine braking alone would provide a smoother speed reduction. Furthermore, experience from the passenger cars trials suggested that an “Opt-In” function was not necessary, as the ISA system would reinstate speed limiting as soon as the vehicle speed fell below the speed limit.

Due to the weight classification of the truck, the speed limits incorporated in the digital speed limit map for cars needed adjustment in line with speed regulations for trucks. Thus on a single carriageway rural roads a truck of this type may not exceed 50 mph whereas a car can travel at up to 60 mph.

The trial design followed the design developed for the ISA car trials, i.e. there were before, during and after phases. Phase 1 (before) lasted for 2 weeks; Phase 2 (during) lasted for 6 weeks; and Phase 3 (after) lasted for 1 week/ this gave a total trial length of 9 weeks.

The truck was placed in service with a logistics company that had a parcel delivery and collection service in Leicestershire running from a base in the city of Leicester to a local town, Hinckley. This route included a number of villages. The company assigned a dedicated driver to each delivery route and therefore the truck was driven by a single driver.

The driving was carried out on a mix of roads with (truck) speed limits of 30 mph, 40 mph and 50 mph. Figure 14 shows how the distribution of speed was affected by ISA on 30 mph roads. Very si milar results were obtained on 40 mph and 50 mph roads. Like the car ISA, the truck system did not cut off acceleration sharply at the speed limit. Nevertheless the results demonstrate the effectiveness of the ISA system in curtailing speeding. In addition, a carry-over effect of using the ISA system was noticeable on 30 mph roads, such that speeding was reduced in the after period.

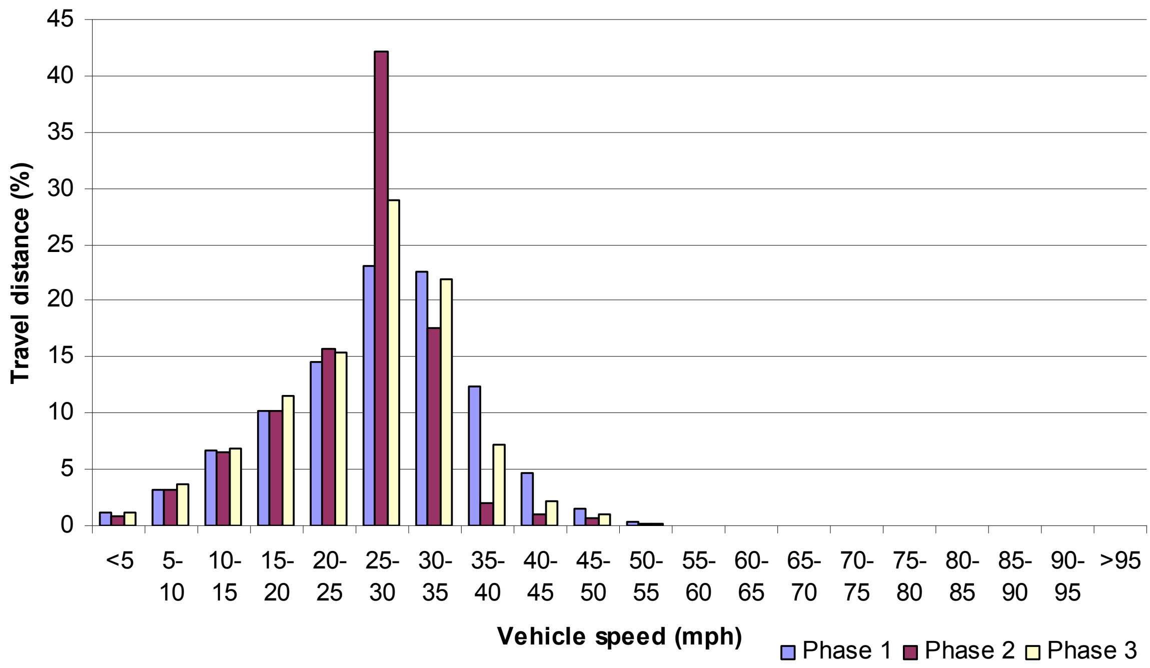


Figure 14: Overall speed distribution in 30 mph zones

Figure 15 compares overriding of ISA across speed limits. The number of "opt-outs" is shown on the left, and the proportion of distance travelled with ISA overridden is shown on the right. The participant did not override the system at all on 40 mph roads and overrode the system only once on

50 mph roads. There was a relatively high frequency of overriding on 30 mph roads, where drivers are most likely to encounter vulnerable road users.

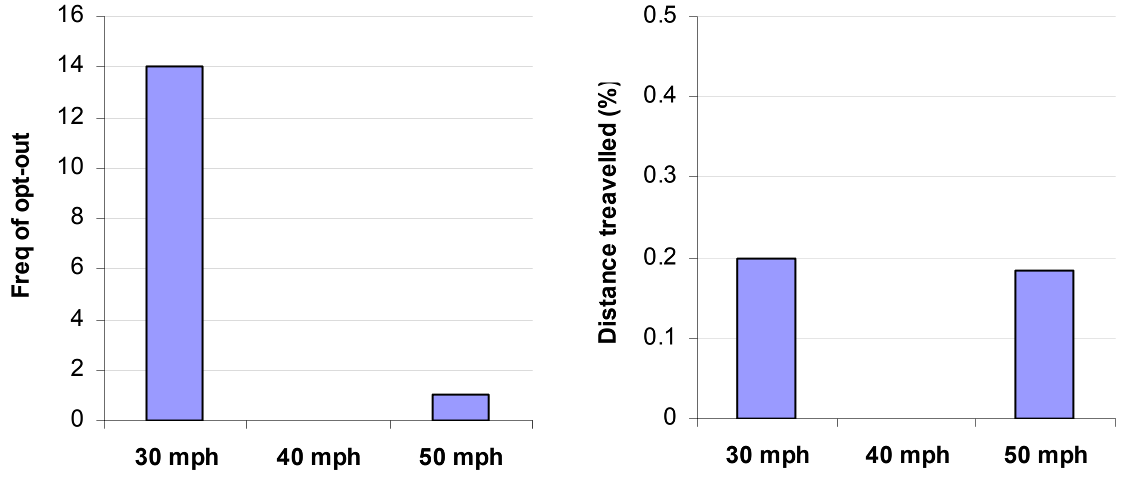


Figure 15: Comparison of overriding behaviour across speed zones

Mean and 85th percentile speeds were reduced overall in Phase 2 as compared to Phase 1, and then went up again in Phase 3. Figure 16 compares the proportion of distance travelled when the vehicle speed was over the speed limit. It clearly demonstrates that ISA effectively diminished speeding.

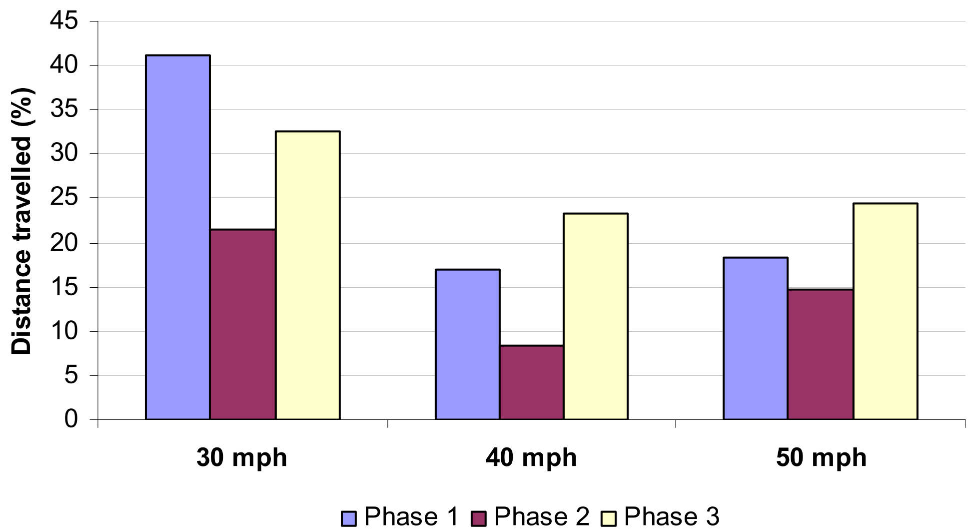


Figure 16: Percentage of distance travelled over speed limit across trial phases

Driver acceptance of the ISA system was measured using the same questionnaire as the one administered to the car drivers As can be seen in Figure 17, the participant's acceptability rating decreased following experience with the system. Ratings of usefulness and satisfaction with ISA systematically declined beyond the removal of the system, suggesting that acceptance was low.

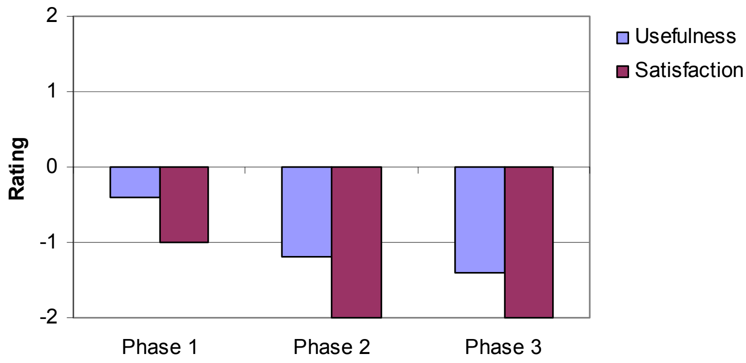


Figure 17: Acceptability ratings on dimensions of 'usefulness' and 'satisfaction'

Several sets of questions were also included to elicit the truck driver's opinion about the ISA system in more detail. In this truck driver's opinion, the introduction of ISA would decrease traffic safety, the joy of driving, the ease of overtaking and surprisingly the ease of keeping to the speed limits. Similarly, he believed that ISA would increase feelings of stress, accident risk, pressure from other traffic and the feeling of being controlled. The driver was unsure whether the system increased his attentiveness to traffic and following distances (i.e. ratings were at the mid-point). Experience with the system seemed only to confirm and strengthen his negative attitude to ISA.

Following experience of ISA, he could only justify the imposition of ISA for novice drivers, speed offenders and those who had recently regained their licence. His trust in the system, having gained experience of ISA, was substantially lower than he had expected, and his trust continued to decline into Phase 3. He was unwilling to have an ISA installed in his truck even if its use was voluntary. Similarly he disapproved of any compulsory fitting of ISA to all new vehicles or the mandatory fitment of ISA on all trucks.

It can be concluded that the participating driver had a general dissatisfaction with and mistrust of the ISA system. He appeared to start the trial with a negative attitude towards ISA and his experience with the system did not change his beliefs. However, the ISA system was effective in curtailing speeding across all speed limits.

Figure 18: Suzuki Bandit 650S

4.3 Motorcycle trial

The selected vehicle was a Suzuki Bandit 650S, shown in Figure 18.

A modular ISA system was developed in which each component was sufficiently small that it could be concealed on the motorcycle. The modules were controlled via software and hardware interfaces packaged in a commercial Personal Digital Assistant (PDA). The PDA was used as an on-board data logger

The motorbike's location was determined using a GPS system. Unlike the ISA car and truck applications, the ISA motorcycle did not use an on-board digital map to identify the position of changes in speed limit. Instead, the system on the motorbike used "virtual beacons" to locate changes in speed limit. A "virtual beacon" is a circular zone of influence around a speed limit change.

The ISA system had three different states:

- **Non-Intervention phase**, when the bike was below the speed limit.
- **Warning phase**, when the bike had slightly exceeded the speed limit.
- **Intervention phase**, when the bike had significantly exceeded the speed limit.

If the motorcycle's speed was less than the Warning limit for the given speed limit, for example 53 mph in a 50 mph zone, the ISA system would stay in the "Non-Intervention" state. If the motorcycle's speed was more than the Warning Limit but less than the Intervention Limit, for example 56 mph in a 50 mph zone, the bike would enter the "Warning" state. Finally, if the motorcycle's speed was higher than the Intervention Limit, for example 60 mph in a 50 mph zone, the bike would enter the "ISA Intervention" state.

The intervening stage of the ISA system on the motorcycle used a reduction in throttle demand to reduce engine power and hence aided speed reduction. Due to the dynamic characteristics of a two-wheeler, no intervention was made to the motorcycle's braking system. An additional cable was attached to the bike's throttle closing cable, which was then linked to a mechanical actuator fitted in the rear pannier of the motorcycle.

The mechanical actuator acting on the throttle cable was designed to be providing a force that could hold the throttle at current position but not close it against the rider's effort. When the rider released the throttle, either to slow down or to change gear, the actuator was then able to close the throttle. This approach minimised the risk that the throttle would be closed unbeknown to the rider.

The ISA motorcycle differed from the other ISA systems developed in this project because it had a Warning Phase prior to implementing Intervention. The main **visual** display aspect of the Human Machine Interface (HMI) implemented on the ISA motorcycle was similar in concept to that used on the other ISA vehicles. The current speed limit was displayed on a LED matrix screen located directly in front of the rider (Figure 19). Additional visual indications were given by a pair of red LEDs fitted to the left and right hand upper edges of the motorcycle windshield (Figure 19), closer to the rider's line of sight. With the ISA system activated, the LEDs flashed when power reduction was about to be initiated.

Figure 19: The ISA motorcycle system elements

The change of speed limit was also indicated to the rider by **auditory** alerts conveyed through earphones worn by the rider and connected to the ISA motorcycle system. **Tactile** alerts were given to the rider by means of a vibration unit installed underneath the motorcycle's seat, and were initiated in conjunction with visual and auditory alerts as described above. The tactile alerts were designed to provide additional support to notification of ISA status to the rider.

The ISA system also included an overriding function. The rider could temporarily turn off the ISA system by pressing the Opt-Out button (Figure 19); the ISA would be resumed upon entering a new speed limit zone or when the speed was dropped below the speed limit.

During the **Warning** phase, when the vehicle was slightly above the speed limit, the following inputs were provided to the rider:

- The rider would see the warning lights mounted on the screen flash intermittently
- The rider would feel the shaker located in the saddle pulse intermittently
- The rider would hear a slow beeping audio alert

If the ISA motorcycle entered the **Intervention** phase, when the vehicle had significantly exceeded the speed limit, the following inputs were supplied to the rider:

- The rider would see the warning lights mounted on the screen flash quickly
- The rider would feel the shaker located in the saddle pulse quickly
- The rider would hear a fast beeping audio alert
- The rider would feel the twist grip roll closed as the power of the vehicle was reduced by the actuator

The trials were held on a closed circuit at MIRA. Speed signs were installed on the track. Before the trial commenced, each rider was given a briefing to explain how the ISA system worked and how the trial would be carried out. Although an overriding function was built in to the ISA system, the participants were asked not to override, in order to gain as much experience of using the ISA system as possible. Three systems were tested in the trial:

1. Advisory ISA, which provided speed limit information and warning to the rider

2. Assisting ISA, which functioned the same as the Advisory system but also reduced throttle output when the speed exceeded preset values

3. Information system, which functioned the same as the Advisory system but also provided route related information such as the layout of an upcoming junction etc.

The order of administering the Advisory and Assisting ISA systems was counterbalanced across all participants to avoid bias because of the order of experiencing one or the other version of the system. The Information system was always administered after the participants had completed both ISA systems. Upon completion of the trial, each participant was invited to comment on the ISA systems and discuss possible improvements. In addition to the digital data, a series of questionnaires was administered.

To expedite the trials the first riders were drawn from thpse working at MIRA, though none of the participants were involved in the development of the ISA motorcycle. Invitations were also issued to a range of motorcyclists whose names were provided by the members of DfT's Advisory Group on Motorcycling. Thirty males and three females took part.

Questions sought to determine riders acceptability of the three systems tested. Rider acceptance was measured using the same acceptability scale as used elsewhere. As can be seen in Figure 20, riders' usefulness ratings of the ISA systems increased following experience with the ISA system. Riders seemed disappointed with the information system and their usefulness ratings significantly decreased following experience with it.

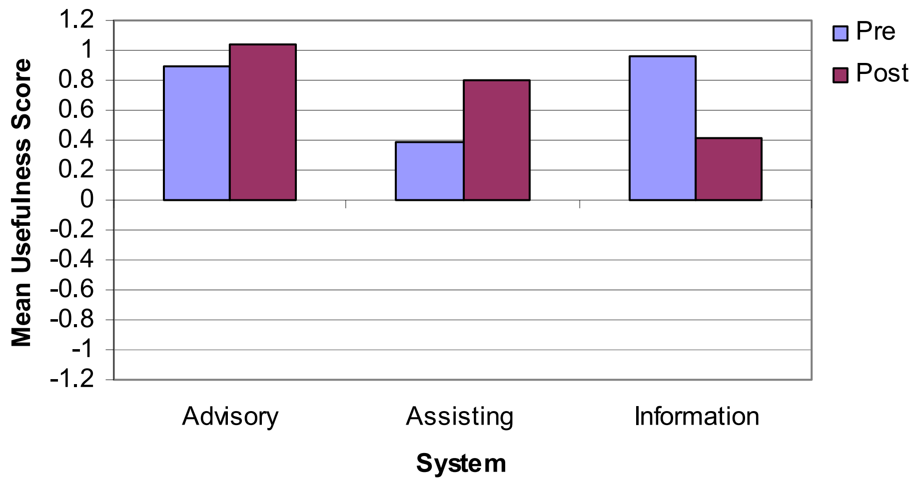


Figure 20: Acceptability rating for the dimension of "usefulness"

Riders' satisfaction scores is shown in Figure 21. It is interesting to note that riders were less satisfied with the advisory system following their test ride than they had originally expected but more satisfied with the assisting system. The difference in ratings was not significant however. Riders' satisfaction with the information system was rated substantially lower following experience with the system.

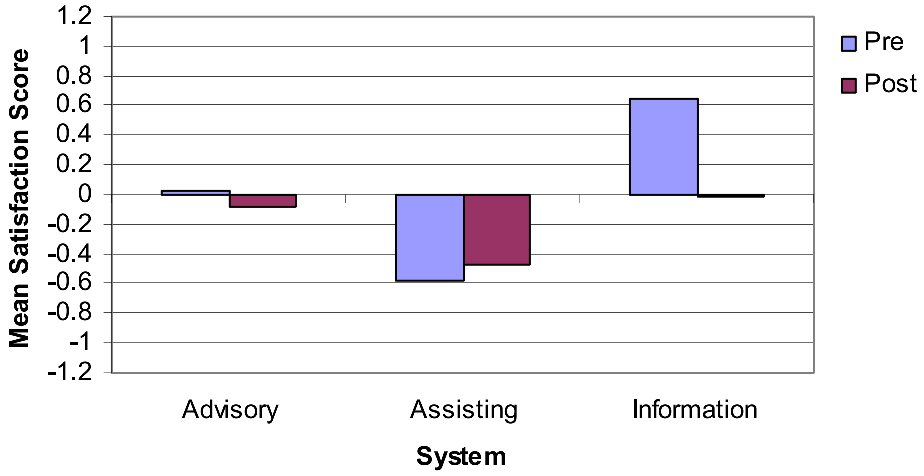


Figure 21: Acceptability rating for the dimension of "satisfaction"

Several sets of questions were designed to tap riders' opinion about the ISA systems following their experience of each system. The first set of questions focused on how the three systems would change various aspects of riding. The results are depicted in Figure 22. Riders agreed that all the systems would increase traffic safety. Beliefs expressed also suggested that the introduction of all three systems would increase riders' irritation, stress and feelings of being controlled and decrease the joy of riding.

The information system was significantly less likely to increase the feeling of being controlled than both the advisory and the assisting system. The assisting system was rated as significantly more likely to decrease the joy of riding compared to the advisory and information systems. Riders thought all the systems were likely to reduce the risk of an accident. The advisory system was believed to be more likely to reduce their accident risk than the assisting system. This is perhaps a reflection of riders' concerns regarding the safety implication of the assisting system. Riders believed overtaking would significantly decrease when riding with the assisting system compared to the advisory and information system.

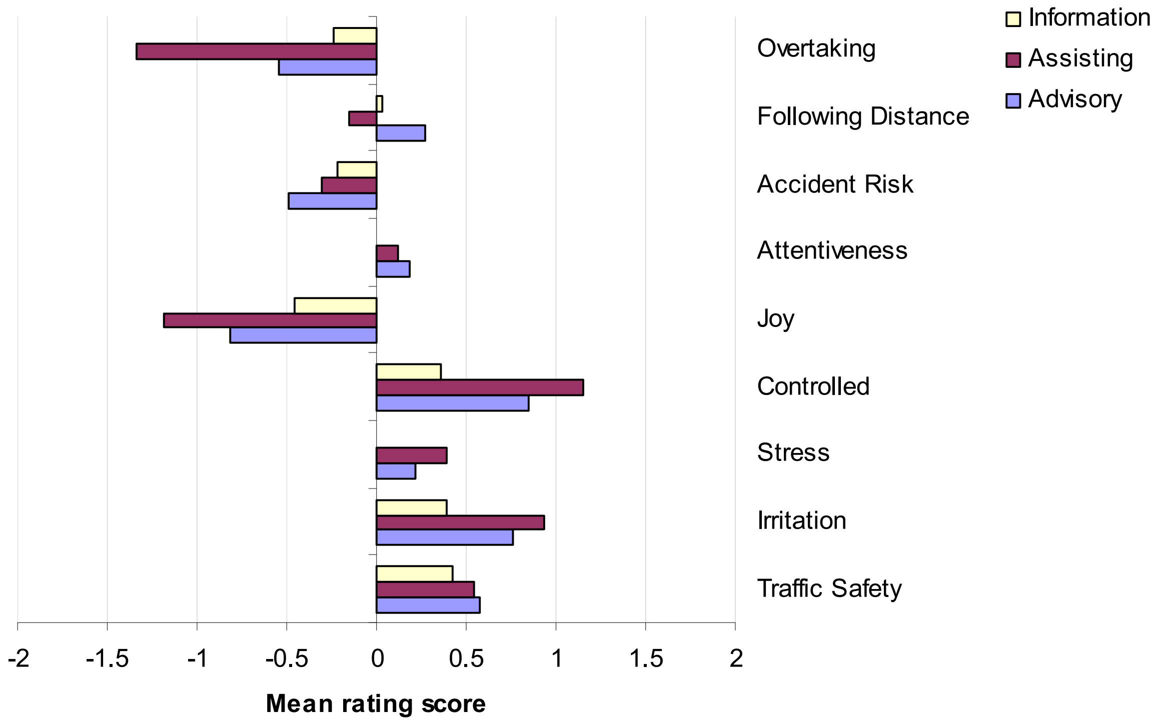


Figure 22: How do you think the following factor would change when riding the three systems compared to riding without any system on your motorcycle?

Another set of questions explored for which rider groups the participants felt the systems were most justified. ISA systems appeared most justifiable for young or novice riders and speed offenders. Riders still believed an advisory ISA was more justifiable for speed offenders than an assisting ISA which would serve to limit repeat offenders' speeds.

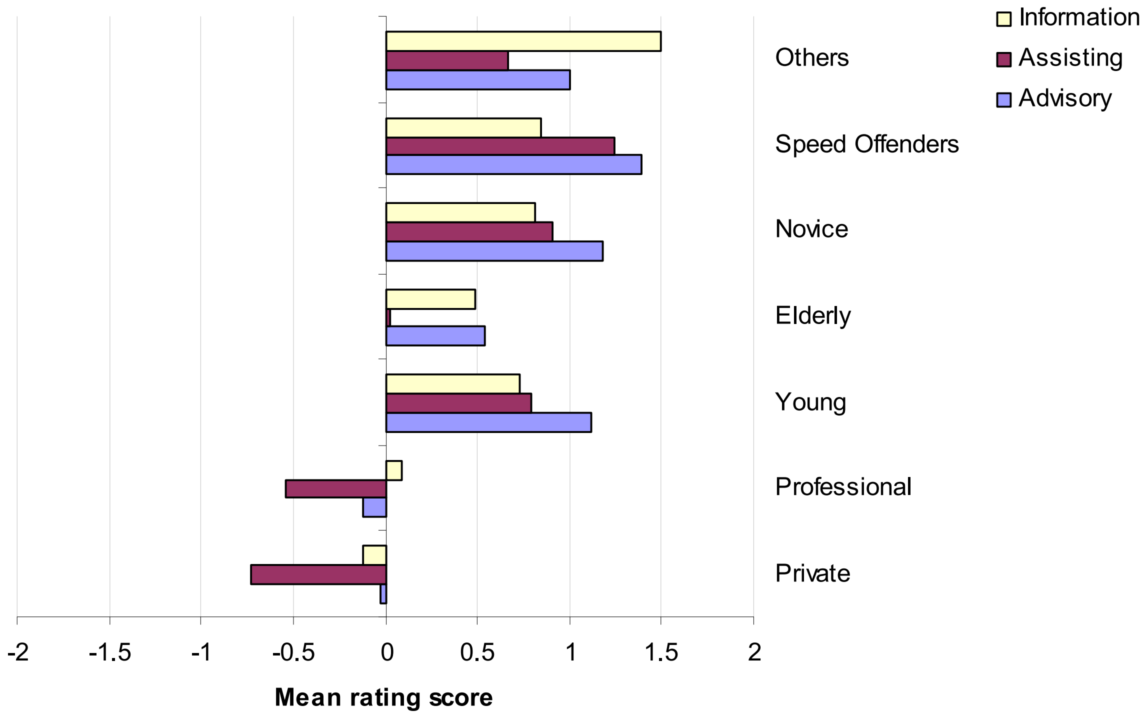


Figure 23: How justified do you think the system would be for the different categories of riders?

Despite reservations expressed by riders in terms of the justifiability and potential utility of the ISA systems, Figure 24 suggests that 64% (of which 36% showed a definite interest) of riders would be willing to consider having an advisory ISA system fitted to their machine. 15% of riders showed a strong interest in having an assisting ISA system fitted and a further 24% would consider having this system installed. Interest was strongest for the information system, despite the low ratings regarding this system's acceptability. Here 70% of riders showed willingness to having this system fitted, with 30% confirming a strong interest.

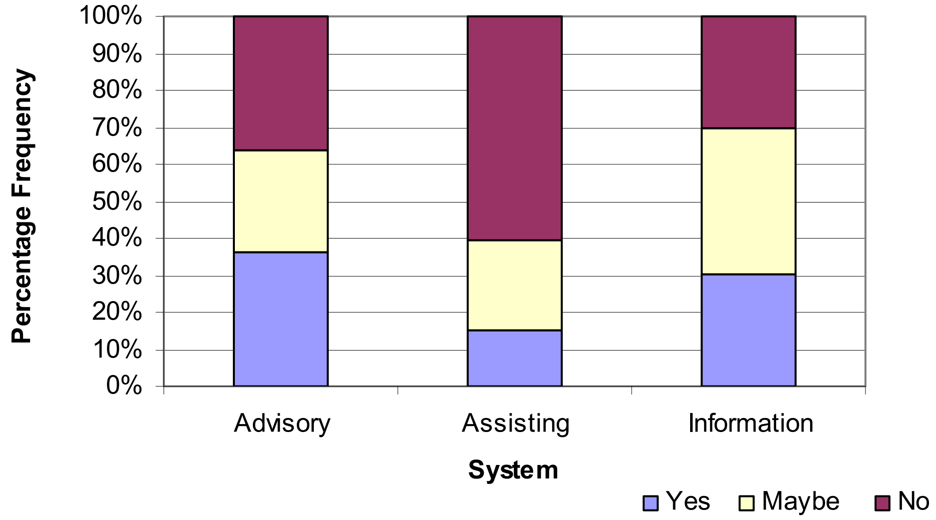


Figure 24: Willingness to install the systems

In the analysis of the logged speed data, an evident 'novelty effect' was observed in that most participants appeared to 'try out' the ISA system by attempting to go over the speed limit in order to experience it. This inevitably influenced mean speed and percentage of speeding distance or duration. This novelty effect was presumably due to the fact that the motorcycle trial was a short-term trial as opposed to the car trials which gave the drivers four months of experience with ISA, and it could be expected that this novelty effect would disappear with increased exposure.

In conclusion, the motorcycle work demonstrated that it was feasible to create an ISA motorcycle that offered a reliable, safe and effective proof-of-concept demonstrator. The results provide some promising evidence regarding ISA which until now has met with considerable resistance from the motorcycling community. Although riders expressed a greater reluctance to use and trust the assisting ISA system, the trial did demonstrate that experience with the ISA systems improved riders' evaluations of their potential. Final comparisons of the number of riders who would at least consider having the systems fitted on their machines were surprisingly positive with 39% of riders willing to consider having an assisting ISA fitted. Prior experience with assisting systems such as ABS indicates that there may be more initial resistance to them on the part of riders than there is to similar systems on the part of car drivers. However, once the benefits are clear, acceptance and take-up usually increase. In the future, the acceptability and consequent take-up of ISA technology may go through a similar cycle.

5 Simulator Experiments

The simulator study was designed to investigate the impact of driving with ISA on overtaking decisions and overtaking quality. The effect of both mandatory (non-overridable) and voluntary ISA were studied. The work was carried out on a driving simulator, which and allowed the presentation of a variety of overtaking scenarios in a safe and controlled test environment. The driving situation tested was driving on a rural road, since it is on such roads that errors in overtaking are likely to result in serious consequences.

It was though that, If drivers understood the limitations placed on their behaviour by ISA, they might choose to overtake less frequently. If, however, drivers failed to appreciate the nuances of ISA, they might continue to overtake and hence place themselves in risky situations. However with the possibility of using the "opt-out" feature to override ISA, such problems might not occur with Voluntary ISA.

Drivers had two visits to the simulator, one for Mandatory ISA and one for Voluntary ISA. During each visit, they completed two drive, with the only difference between those two drives being the proportion of ISA vehicles in the surrounding traffic. Each of the drives contained 10 overtaking scenarios: in half of these scenarios ISA was provided, in the other half ISA was not available (as indicated by the in-vehicle interface). Twenty-six drivers completed both visits, 12 males and 14 females.

Figure 25: The Leeds Driving Simulator

The experiment was performed on the University of Leeds Driving Simulator, shown in Figure 13. This has a sophisticated motion base to give drivers a realistic sense of motion and incorporates a full size vehicle and high-resolution graphics

The road driven was a two-lane rural road interspersed with various "2+1" sections, where the road would open up to provide an extra lane in the travel direction while opposing traffic still had only one lane. The length of the 2+1 section was varied. There were also some overtaking possibilities on "1+1" (one lane in each direction) sections. Drivers were encouraged to attempt to overtake by having to follow a slow lead car.

There were two main types of data of interest: the propensity to overtake and the safety of any such behaviour. In terms of overtaking attempt, typical indicators were attempted overtaking manoeuvres and abandoned overtaking manoeuvres. A successful overtaking was defined as one that did not, in the 2+1 road sections, end up with any encroachment into the hatched area where the road narrowed back down to a 1+1 layout.

Overtaking safety was defined in terms of how close the driver came to the overtaken vehicle both in pulling out and in pulling back, as well as in terms of encroachment into the hatched area.

Each driver encountered a total of twenty overtaking scenarios per drive. Voluntary ISA did not affect the number of overtaking manoeuvres as compared with driving without ISA.

However, with mandatory ISA, the number of attempted manoeuvres was almost halved. Drivers overrode of the voluntary system when faced with an overtaking decision.

When driving with mandatory ISA, there was a 59% reduction in the number of successful overtaking attempts made. This trend was not apparent when driving with a voluntary ISA system where the number of successful attempts when driving with ISA on and off was almost identical. Abandoned overtaking manoeuvres were rare, but tended to happen when mandatory ISA was active.

In terms of safety of overtaking outcome, Figure 14 shows that, when driving with the mandatory ISA system, six drivers never encroached on the hatching, and most of the other drivers made only a small number of encroachments. Two drivers encroached in almost all scenarios. Comparing this to Figure 15 however, it can be seen that drivers were less likely to encroach on the hatched area when driving with the voluntary ISA system with over half of the drivers making only 2 or fewer encroachments.

In addition, the amount of time spent in the hatched area was measured, as an index of encroachment severity. In general, when mandatory ISA was active, encroachments were more severe, with drivers spending an additional one second in the hatched area.

An additional measure of safety was obtained from the separation distances between the driver and the lead vehicle whilst overtaking. As the driver instigated an overtaking manoeuvre, the minimum distance between the front of their vehicle and the rear of the lead vehicle was recorded. The minimum

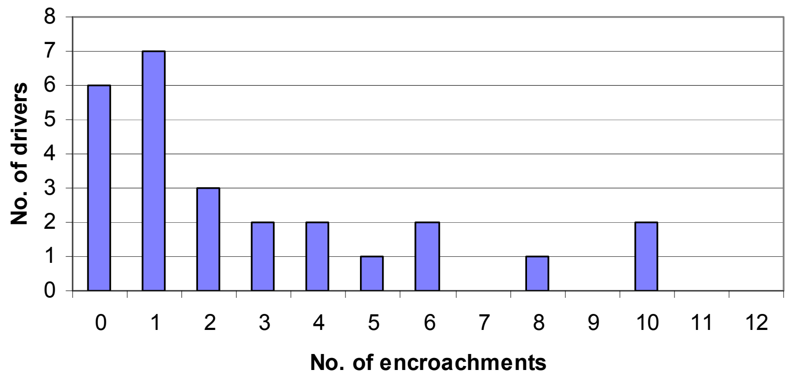


Figure 26: Frequency of encroachments with mandatory ISA

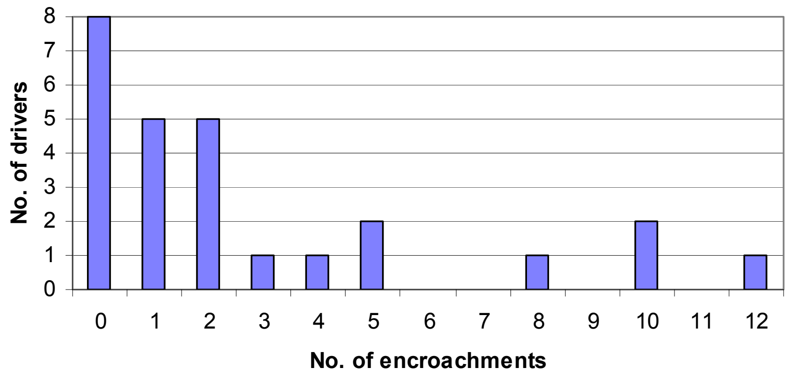


Figure 27: Frequency of encroachments with voluntary ISA

distance between the rear of the driver's car and the front of the lead vehicle was also recorded as the overtaking was concluded. These two measures of distance provide an indication of "cutting-in" and can be considered to be a measure of aggressiveness or lack of planning.

When either ISA systems was activated, drivers tended to adopt a shorter following distance to the vehicle in front, just prior to an overtaking manoeuvre. This was presumably a strategy to reduce their overtaking time when speed-limited. There were also some signs that drivers tended to cut in more aggressively when driving with mandatory ISA. Cutting in was more aggressive on the 2+1 sections with a shorter length.

Overall the behavioural results indicated that the drivers became less inclined to initiate an overtaking manoeuvre with Mandatory ISA. That would be positive for safety, in that overtaking manoeuvres tend to be inherently risky. On the other hand there was increased risk when making an overtaking manoeuvre. In addition to this, when Mandatory ISA was active, drivers were more likely to have to abandon an overtaking manoeuvre, presumably due to running out of road. These effects were not apparent in the case of the Voluntary ISA system where there was no difference in the number of attempted and successful overtakes as compared with no ISA. The drivers are able to routinely disable the voluntary ISA system when making an overtaking manoeuvre.

6 Predicted Accident Savings from ISA

For the work on accident prediction and cost benefit analysis, three variants of ISA were envisaged.

1. **Advisory ISA** where speed limit is displayed on the dashboard and an auditory signal is given when speed limit is exceeded, or when entering a new speed limit.

2. **Voluntary ISA** much like that used in the car and truck trials, where drivers can choose to override the system

3. **Mandatory ISA** where overriding is not possible.

Two scenarios or visions of the future were developed for how ISA would be implemented:

1. **Market Driven:** Vehicle owners (and operators) may choose to purchase and fit a commercially available variant of ISA variant, which initially tends to be Advisory ISA.

2. **Authority Driven:** Although this scenario begins with some drivers choosing to equip their vehicles with ISA (as in the Market Driven scenario), the Government or the EU at some point requires the fitment of Voluntary ISA on new vehicles and the retro-refitting of existing fleets to accelerate take-up and ensure that the full potential of ISA is realised. Eventually, once most vehicles are fitted, *usage* of ISA becomes compulsory so that Voluntary ISA is turned into Mandatory ISA.

The major source of information on speed changes with ISA was the set of field trials in this project with the converted cars. The impact of speed changes on crash risk and crash severity was modelled using empirically derived relationships various studies. Where possible, relationships for each speed limit were used. Three combinations of such models were applied. The results here are given for what was termed the “Base Combination” of speed-to-crash-risk models.

Figure 28 shows the predicted savings in crashes over time under the Market Driven scenario. The reductions shown are in comparison with the “do-nothing” (no ISA) case. The safety impacts rise gradually in line with penetration of ISA. By 2070 the Market Driven scenario is achieving a 16% reduction in fatal crashes, a 10% reduction in serious injury crashes and almost a 5% reduction in slight injury crashes, when compared to the no-ISA baseline for the same year.

In contrast, the Authority Driven scenario, shown in Figure 29, delivers a 42% reduction in fatal crashes from 2045. In that year, the retro-fitting of older vehicles and eliminating the override of ISA produces a step change in speed compliance, so that all vehicles fully comply with the speed limits. The corresponding reduction in serious and slight injury crashes is 38% and 23% respectively. Beyond that year there is no further increase in the effectiveness of ISA — hence the flatlining of the reductions after 2045.

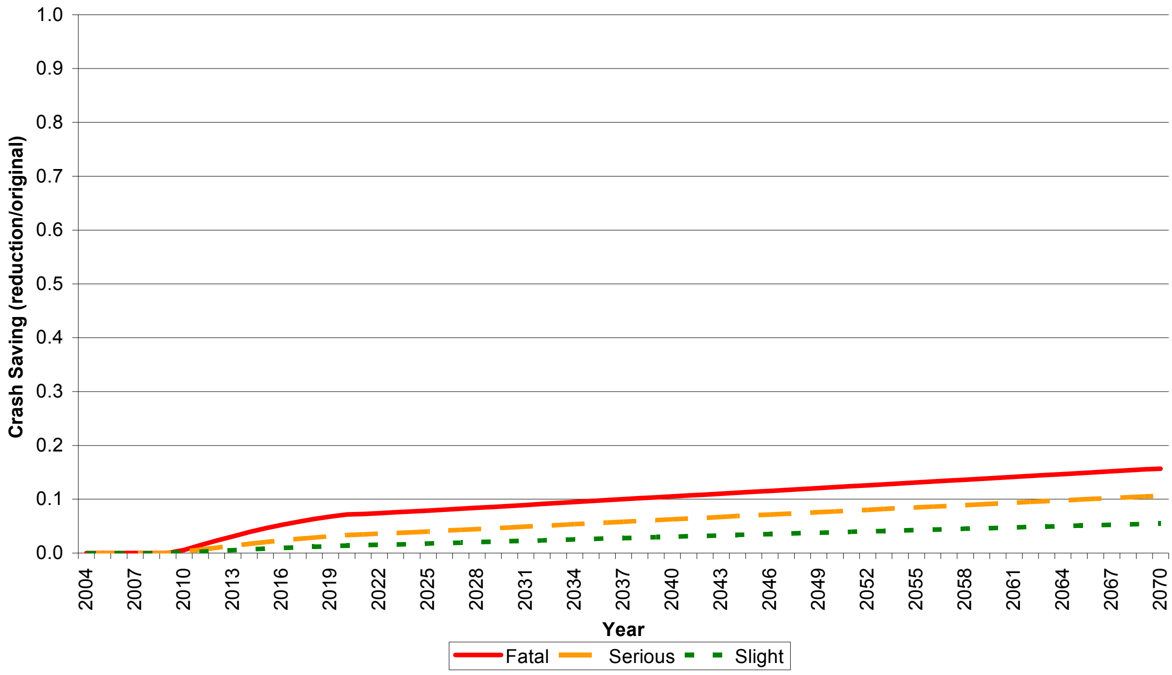


Figure 28: Predicted crash reduction over time for the Market Driven scenario

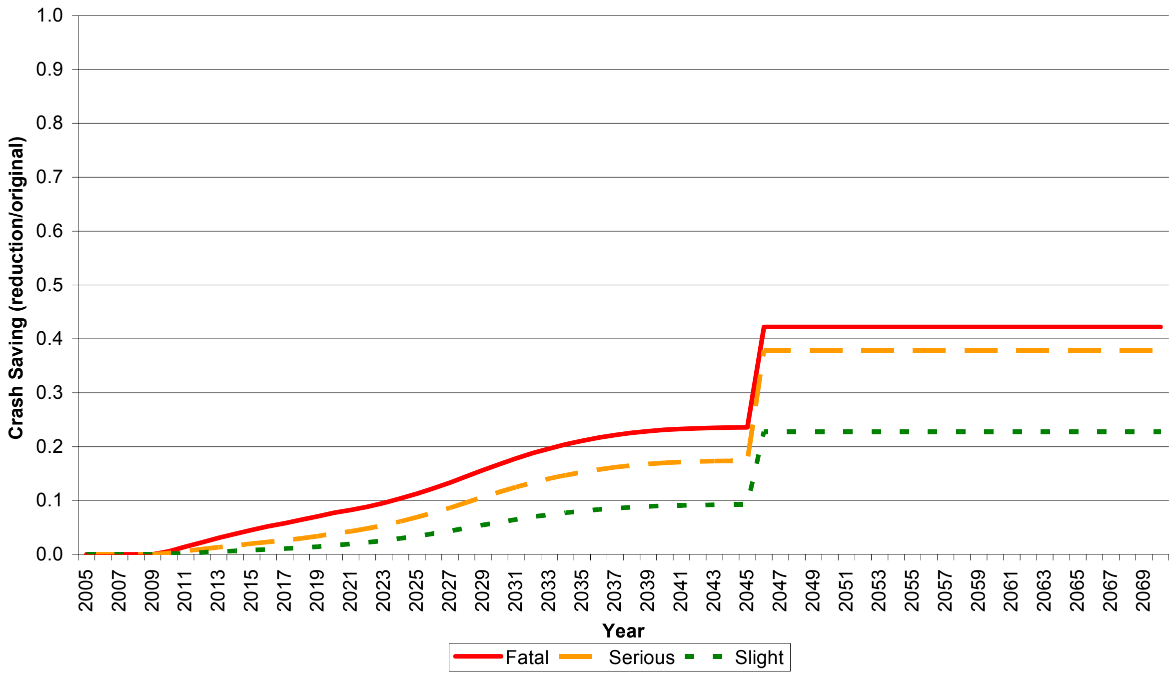


Figure 29: Predicted crash reduction over time for the Authority Driven scenario

Under the Market Driven scenario, ISA saves 10% of fatal accidents and 6% of serious injury accidents over the period from 2010 to 2070, as compared to respective savings of 26% and 23% under the Authority Driven scenario with mandatory usage in 2045..

The prediction is that ISA has the greatest benefits on 30 mph roads. On such roads, the Market Driven scenario predicts a 5% reduction in high severity accidents, those resulting in death or serious injury. This figure rises to 32% under the Authority Driven scenario.

7 Benefits and Costs of ISA

For the cost benefit analysis, only the benefits from the safety impacts of ISA were covered. The effects of ISA on fuel consumption, emissions and network reliability were not considered. Costs of ISA were based on the current costs of the equipment with comparatively small reductions estimated over time. It was concluded that the public costs — for creating a keeping up-to-date a national speed limit database and for transmitting updates of that database into vehicle — was comparatively small. The standard Department for Transport procedures for cost benefit analysis were used. Here only the results using the Base Combination of models for the speed to safety relationship are provided. Various alterations to the scenarios that were modelled are also not covered.

Table 1 shows the total value over the period of (1) the costs of purchasing ISA and of providing the information on speed limit needed by ISA systems and (2) the benefits of ISA in terms of crashes prevented and crashes reduced in severity. It can be seen that the benefits substantially exceed the costs.

Table 1: Net present value of costs and benefits

Implementation Scenario	**Net Present Value of Costs (2006 £million)**	**Net Present Value of Benefits (2006 £million)**
Market Driven	£16,903	£31,316
Authority Driven with compulsory use of ISA in 2045	£26,629	£84,155

The ratio of benefits to costs is a standard measure of whether a scheme or implementation is worth pursuing. The overall benefit to cost ratio for the Market Driven scenario was 1.9 and for the Authority Driven scenario was 3.2. Thus for both scenarios the benefits considerably outweigh the costs.

8 Conclusions

The car and truck trials demonstrated that ISA is now a mature technology which is capable of delivering substantial reductions in excessive speed and thereby considerable benefits in terms of safety. The behavioural results from the car trials show that the overridable ISA that was used by the participants reduced the amount of speeding among every category of user. It also affected driving on every road category, except the 60 mph rural roads where there was comparatively little speeding by the participants in the pre-ISA baseline.

The use of an overridable ISA system in the car trials provided an opportunity to observe differential usage. ISA was overridden the most on motorways, followed by built-up areas (20 and 30 mph zones). Urban environments are where drivers are most likely to encounter conflicts with vulnerable road users such as pedestrians and cyclists. Thus there is some tendency for ISA to be overridden on roads where it is perhaps needed most. In term of sub-groups within the driving population, male drivers and young drivers overrode the system more than their counterparts regardless of speed zones. Given that these two groups of drivers also drove faster and had a higher percentage of distance travelled over the speed limit than their counterparts, there is a pronounced tendency for ISA to be overridden by those drivers who in safety terms stand to benefit most from using it. It was also found that speed intenders overrode the system more frequently than non-intenders on motorways, and that private motorists were more likely to override in built-up areas while fleet drivers more frequently overrode on motorways. These findings suggest that there is a case for supporting a voluntary ISA with incentives for drivers to comply.

There were interesting differences between the impacts of ISA on the driving of the private motorists and the impacts on the fleet drivers. The fleet drivers tended to override the system most on 70 mph roads, whereas the private motorists overrode most on 30 mph roads.

Successful implementation of ISA would ultimately rely upon the attitude of the general public. The current analysis found promising support for the finding that long-term experience with an ISA system increases acceptability. Despite an initial dip in acceptability, the rating of the ISA system in terms of usefulness and satisfaction, improved over time. Participants rated certain traffic environments, particularly those where it was easier to speed, as being more risky with ISA. Overtaking was also raised as a concern. Nevertheless, in the majority of driving situations, participants felt that risk was reduced when driving with ISA as compared to unsupported driving. Similarly participants believed that attention to the speed limits and to potential hazards (e.g. other road users, pedestrians) and conflicts had increased. Support for the implementation of ISA was also reasonably strong, with 56% of participants approving of compulsory fitting of ISA to all new vehicles. However, those expressing strong intentions to speed demonstrated the most resistance to ISA. This suggests that the voluntary implementation of ISA may fail to target those who are most in need of the system.

Adapting ISA to a motorcycle environment was a more challenging proposition both in terms of the need to minimise weight and system volume and because of the requirement to consider the very different vehicle dynamics of a motorcycle. A demonstration ISA motorcycle was created that has offered a reliable, safe and effective vehicle for riding in user assessment trials within a test track environment. The response from riders was somewhat mixed.

The analysis of future accidents using the favoured Base Combination of crash reduction models indicates that, over a 60-year period from 2010 to 2070, the Market Driven implementation scenario would be expected to reduce fatal accidents by 10% (approximately 15,400 fatal accidents), serious injury accidents by 6% (96,000 accidents), and slight injury accidents by 3% (336,000 accidents).

The same combination of crash reduction models predicts that, over the 60-year, period the Authority Driven implementation scenario would be expected to reduce fatal accidents by 26% (approximately 43,300 fatal accidents); serious injury accidents by 21% (330,000 accidents), and slight injury accidents by 12% (1.3 million accidents).

The economic benefit associated with the predicted crash reductions is substantial. Applying the Base Combination of accident prediction models, the Market Driven implementation scenario is expected to result in benefits 1.9 times greater than the cost of introduction. The Authority Driven implementation of ISA is expected to produce economic benefits 3.2 times greater than the investment costs. Under both the implementation scenarios modelled, and whatever combination of accident prediction models is applied, the benefits considerably outweigh the costs.

List of Project Reports

A series of detailed reports have been prepared under the ISA project. They are:

1. Implications of Travel Patterns for ISA
2. Results of Field Trial 1
3. Results of Field Trial 2
4. Results of Field Trial 3
5. Results of Field Trial 4
6. Results of Truck Trial
7. Results of Motorcycle Trial
8. Simulator Experiments
9. Overall Field Trial Results
10. Implementation Scenarios
11. Final Report