isa - UK

***i**ntelligent **s**peed **a**daptation*

Results of Motorcycle Trial

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EXECUTIVE SUMMARY

This deliverable describes the implementation and assessment of an Intelligent Speed Adaptation (ISA) system for motorcycles. This work was part of the ISA project, which developed ISA systems for passenger cars, motorcycles, and trucks, and tested the car and truck systems in real-world field trials.

The objectives of the work reported here were:

- To define a functional specification for an ISA appropriate for a motorcycle
- To identify the additional safety hazards associated with an ISA when being used by motorcyclists
- To select an appropriate example motorcycle and to define an ISA architecture suitable to be installed on the selected motorcycle as a proof of concept
- To assess ISA functionality and performance as well as user acceptance

A suitable vehicle was acquired and a number of design alternatives considered. In the end, two forms of ISA, one with an additional variant, were implemented on the motorcycle. Riders were given the opportunity to compare one with another so that the researchers could compare rider attitudes to and behaviour with the alternatives. The systems implemented were an Advisory ISA and an Assisting ISA; the variant was an Information ISA. The Advisory ISA provided the rider with the current speed limit via an LED display and used flashing LEDs to alert the rider when the motorcycle was slightly above the speed limit. At the same time there was a beeping audio alert in the rider's helmet and vibration pulses in the saddle. The Assisting system provided the rider with the current speed limit and used a counter-action on the throttle, which was not strong enough however to prevent the rider from keeping the throttle open. When the Assisting system was active, there was a sequential process in which first warning would be issued and then, if the vehicle continues to significantly exceed the speed limit, the throttle intervention would be applied. The Information system provided the riders with travel information (e.g. upcoming traffic lights and junctions) in addition to all functionality that an Advisory ISA system offered. This configuration was designed to investigate whether combining ISA with other rider assistance systems led to a difference in riders' behaviour and acceptance of the ISA system.

The trials were carried out on a closed test track. Thirty males and three females participated in the trial, most of whom were experienced riders. They found the Advisory version to be the most positive in terms of usefulness, but were generally less positive about satisfaction with all versions of the system with negative satisfaction expressed for the Assisting ISA. This is in line with typical results from car trials with ISA.

ISA was perceived by the participating riders as negative in terms of "Joy" and "Overtaking", and was perceived to increase irritation and the sense of being controlled. However, it was perceived to increase traffic safety and decrease accident risk. It was also thought by the participating riders to be most suitable for young riders, novices and speed offenders. Riders were least likely to be willing to install the Assisting ISA. In terms of observed behaviour the Assisting ISA was the most effective in reducing speeding, particularly in the case of aggressive riders. This is in line with results obtained in various trials using ISA for passenger cars.

Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

1.1 Overview of the project

This project has examined the impact of a technology that can assist drivers and riders in maintaining legal vehicle speeds on the road. This concept is called Intelligent Speed Adaptation (ISA). It requires the vehicle and its ISA system to have an awareness of its location (geographical position and heading), data concerning the appropriate local speed limit, and a means of interfacing to the driver/rider and, if necessary, vehicle systems. In this generic concept the vehicle user can then be advised or assisted in maintaining speeds within the legal maximum.

Earlier research on ISA carried out for the Department for Transport, in the External Vehicle Speed Control project (Carsten and Tate, 2000), considered the impact of ISA as implemented on a single passenger car and used in limited road trials. Based upon the results of that earlier work, this project has extended the analysis to longer term, larger trials of ISA on passenger cars, and an initial examination of ISA on other vehicle types.

1.2 Objectives of the project

The main objective of this project was to design and implement ISA functionality on a range of vehicle types to investigate user responses and assess impacts upon road user behaviour.

This vehicle range included:

- A passenger car fleet of 20 vehicles
- A single goods vehicle
- A single motorcycle

This deliverable describes the implementation and results of ISA when fitted to a motorcycle and assessed in a test-track setting with a selected group of motorcycle riders. The objectives of this particular part of the project were:

- To define a functional specification for an ISA appropriate for a motorcycle
- To identify the additional safety hazards associated with an ISA when being used by motorcyclists
- To select an appropriate example motorcycle and to define an ISA suitable to be installed on the selected motorcycle as a proof of concept
- To assess ISA functionality and performance as well as user acceptance

2. DEVELOPMENT OF ISA FOR MOTORCYCLES

2.1 ISA functional requirements

The system implemented on the ISA fleet cars prevented the driver from exceeding the prevailing speed limit by limiting the throttle passed to the engine, irrespective of the throttle demand from the driver. It also applied the foot brake if the vehicle speed exceeded the current speed limit by more than 10%.

The initial concept for the ISA system to be implemented on the ISA motorcycle had a similar form of functionality to the ISA cars and therefore should potentially act to reduce engine power if the local speed limit was exceeded. However it was noted at the outset that such an intervention on a motorcycle should not suddenly override the rider’s throttle demand, since control of transmitted power to the road wheels is an important element in maintaining the dynamic stability of a motorcycle. The important guide to the initial concept development for the ISA motorcycle was to have a functionality realised where the rider should expect the power limitation and the power reduction should be delivered smoothly. Application of other speed retarding mechanisms, such as via the brakes, was considered but was excluded from the final version of system design in order to eliminate the potential impacts on motorcycle dynamics stability (i.e. the nature of a two-wheeled vehicle imposes the inherit danger of sudden deceleration while the vehicle is tilted).

2.2 Potential means for intervention

Considerations of potential means for the ISA intervention were made based on the power generation mechanism of a petrol engine: air, fuel and an ignition source.

Ignition
Altering the ignition timing can lead to a small reduction in power. Interruption of the ignition system can have a major effect on power but the rough and intermittent power delivery could unbalance the rider, while excess fuel accumulating in the engine and exhaust system is likely to lead to unexpected back-firing.

Fuel
Slight reductions in the fuel supply could be used to bring a small reduction in power but larger reductions would lead to incorrect fuel/air mixtures and rough or unbalanced engine running.

Air
A reduction in air entering the engine can be achieved by fitting a second throttle. However, air reduction without a corresponding reduction in fuel delivery would lead to an unstable, misfiring engine that could unbalance the rider.

A fundamental requirement for the ISA motorcycle is to have smooth, progressive power reduction that does not unsettle the rider. This ruled out modifying only the ignition and left a method of reducing air and fuel together as the most practical solution. A further benefit of a combined reduction in air and fuel, without alteration of the ignition, is that there is no possibility of damaging the engine.

Based on the above initial considerations, the following options were investigated:

1. Select a motorcycle with an electronic throttle and modulate signal:
   A motorcycle with an electronic throttle would be the ideal platform as it would allow system design aspects to be parted from the ISA cars. However no motorcycles were available with such a control mechanism.

2. Fuelling of a fuel-injected engine:
   It would be possible to control the fuelling of a fuel-injected engine, and therefore power, by interfacing a secondary control system (such as ISA) to the electronic control units for fuelling. However such a strategy would require access to the manufacturer’s software and hardware design. As this access was not available, this option was disregarded.

3. Fit a second throttle – single-cylinder engine:
   If a single-cylinder engine was appropriate for the ISA trial, a second ISA controlled butterfly plate could be conceived to fit into the carburettor intake to reduce the air/fuel mixture entering the engine over and above the control offered by the rider’s throttle butterfly. Motorcycles powered by a single-cylinder engine were assessed for feasibility but none were found that complied with other selection criteria. This option was therefore disregarded.

4. Fit a second throttle – multi-cylinder engine:
   A similar approach to Option 3 could also be conceived of for a multi-cylinder engine, more common on the type of motorcycle required for the ISA trial. However after an initial examination, it was determined that packaging and space constraints would make a retrofit installation complex, and the controllability of such an intervention might also be questionable. This option was therefore disregarded.

5. Select a motorcycle that incorporates a second throttle mechanism in the original design:
   In a motorcycle with two throttles, the first is controlled by the rider’s throttle grip, the second via the induction manifold pressure and a diaphragm. Such a configuration might allow intervention with the throttle activation by mechanical means and was chosen for further engineering assessment and vehicle selection.

2.3 Selection of vehicle

The purpose of the ISA motorcycle trial was to implement ISA on a typical motorcycle representing mainstream vehicle design. The design team at MIRA considered that such a motorcycle was typically within the 500-750cc displacement range.

In addition, as the ISA motorcycle trial was intended to examine the attitudes and opinions of a wide range of current riders; the selected motorcycle for the ISA trials needed to accommodate this range of riders. Therefore a mid-range motorcycle in terms of engine capacity, size, weight and price, that was easy to ride for both novice and experienced riders, and by men and women, was a goal in vehicle selection. Selected data on a range of motorcycles available in the UK at the period of vehicle selection was compiled as shown in Table 1.

Table 1: Selected data on mid-range motorcycles available in the UK

MFR	Model	Class/Type	Cost (£)	Max Power	Weight (Kg) (no fuel)	Storage	Ergonomics issues
BMW	F650 CS	Roadster	5650	50 bhp @ 6500 rpm	170	False fuel tank/MB	Upright position. Adjust. Hbar and Seat
Ducati	Monster 620	Roadster	4995	63 bhp @ 9500 rpm	179	None	Sports position
Ducati	Multistrada 620	Roadster	5494	63 bhp @ 9500 rpm	183	PA/Fairing/US	Upright position, room around instrument cluster
Honda	CBR600F	Sports	6699	108 bhp @ 12200 rpm	170	PA	Sportier position
Honda	Deauville	Roadster	5999	55 bhp @ 7750 rpm	228	PA	Upright position.
Honda	Shadow VT750C	Cruiser	5499	44 bhp @ 5500 rpm	229	Saddle bag	Easy rider position
Honda	TransAlp XL650V	Roadster	5249	54 bhp @ 7500 rpm	191	TB/PA	Upright position. Low seat option
Honda	VFR800	Sports Tourer	7999	107 bhp @ 10500 rpm	213	TB/PA	Sportier position
Kawasaki	ER-5	Roadster	4999	50 bhp @ 9000 rpm	179	TB/US	Upright position
Kawasaki	Z750	Sports Tourer	4999	110 bhp @ 8200 rpm	195	PA	Sportier position
Kawasaki	ZZR600	Sports Tourer	5999	100 bhp @ 9300 rpm	195	None	Sportier position
Suzuki	Bandit 600S	Roadster	4549	76 bhp @ 10500 rpm	209	TB/US	Upright position. Low seat option
Suzuki	Bandit 650S	Roadster	4549	78 bhp @ 10100 rpm	204	US	Upright position. Low seat option
Suzuki	GSX750F	Sports Tourer	5549	91 bhp @ 10500 rpm	212	US/TB/PA	Sportier position
Suzuki	GSXR600	Sports	6849	118 bhp @ 13000 rpm	161	none	Sports position
Suzuki	SV650S	Sports Tourer	4549	71 bhp @ 9000 rpm	169	US/TB	Low seat option
Suzuki	V-Strom 650	Roadster	5149	66 bhp @ 8800 rpm	190	MB/TB	Upright position
Triumph	Daytona 650	Sports	6499	112 bhp @ 12500 rpm	165	none	Sports position
Yamaha	FZ6 Fazer	Sports	5499	98 bhp @ 12000 rpm	187	TB/PA	Sports position
Yamaha	YZF-R6	Sports	6599	120 bhp @ 13000 rpm	163	None	Sports position

Key
US = under-seat storage
TB = top box storage
PA = pannier storage
MB = magnetic bag

Following further analysis, it was determined that the Suzuki Bandit 650 was the most appropriate vehicle. In addition to the dual-throttle mechanism design, it was considered to be a representative, popular, mid-range motorcycle that was easy to ride and had a comfortable seating position and good power to weight ratio to suit both experienced and novice riders. As a result an example of this vehicle was purchased for detailed engineering assessment, system design and system implementation. The selected vehicle is shown in Figure 1.

Figure 1: Suzuki Bandit 650S

2.4 Selected intervention methods

The initial approach to the engineering modification of the vehicle was to modulate the engine power available by manipulating the second throttle and thereby reducing manifold depression above the diaphragm. Experimentation showed that power control could be affected. However, even when the maximum power reduction was applied there was still sufficient power available for the rider to achieve speeds over 70 mph. As the goal of the test-track trial was to demonstrate vehicle speed assistance functionality at lower speeds (e.g. 30, 40, 50, 60 mph), this was not an acceptable mechanism. It was therefore considered that an alternative throttle intervention mechanism was required.

An alternative approach was then investigated, which used direct mechanical intervention with the motorcycle throttle. An examination of the motorcycle's throttle control revealed that it had two actuator cables connected to it. When the throttle was twisted to accelerate, one of the cables extended, and when the throttle grip was released, the second cable pulled the throttle closed. It was considered that an intervention with the throttle cable mechanism could yield a robust and direct means of controlling throttle opening engine power. To examine this option an additional cable was attached to the throttle closing cable.

This additional cable was linked to a mechanical actuator fitted in the rear pannier of the motorcycle. In this arrangement, an ISA control system could identify the need to reduce speed, and therefore power, by initiating the actuator to pull the throttle closing cable, which would minimise the throttle opening available to the rider and thereby slow the motorcycle down.

Attaching an additional cable to the closing side of the throttle was an efficient design as it provided a relatively simple modification to the vehicle that caused minimum alteration of the original system. In terms of possible system failure modes, if the additional cable failed, the system would automatically revert to its original design condition and the rider would retain full control of the throttle.

Measurement of the forces on the throttle twist grip revealed that the force needed to close the throttle, against the rider's wishes, was much greater than that needed to hold it in its current position. Consequently the mechanical actuator acting on the throttle cable was specified as one that could provide 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 therefore minimised the risk that the throttle would be closed unbeknown to the rider.

2.5 Control architecture

A Control Area Network (CAN) was chosen for the main architecture of the ISA motorcycle system. CAN is a standardised protocol for sending and requesting of information on a serial bus system. The CAN offers a modular approach to link together the elements of the system that can be expanded to accommodate new functions.

A number of stand-alone modules were designed, implemented and connected to form the ISA motorcycle CAN, as illustrated in Figure 2. All the modules could receive or transmit information onto the network. Individual modules interpreted the signal from the CPU and set in motion the appropriate response. Figure 2 indicates that in addition to GPS, the system consisted of a power supply, a display, input/output, and a servo module all controlled via software and hardware interfaces packaged in a commercial Personal Digital Assistant (PDA) platform.

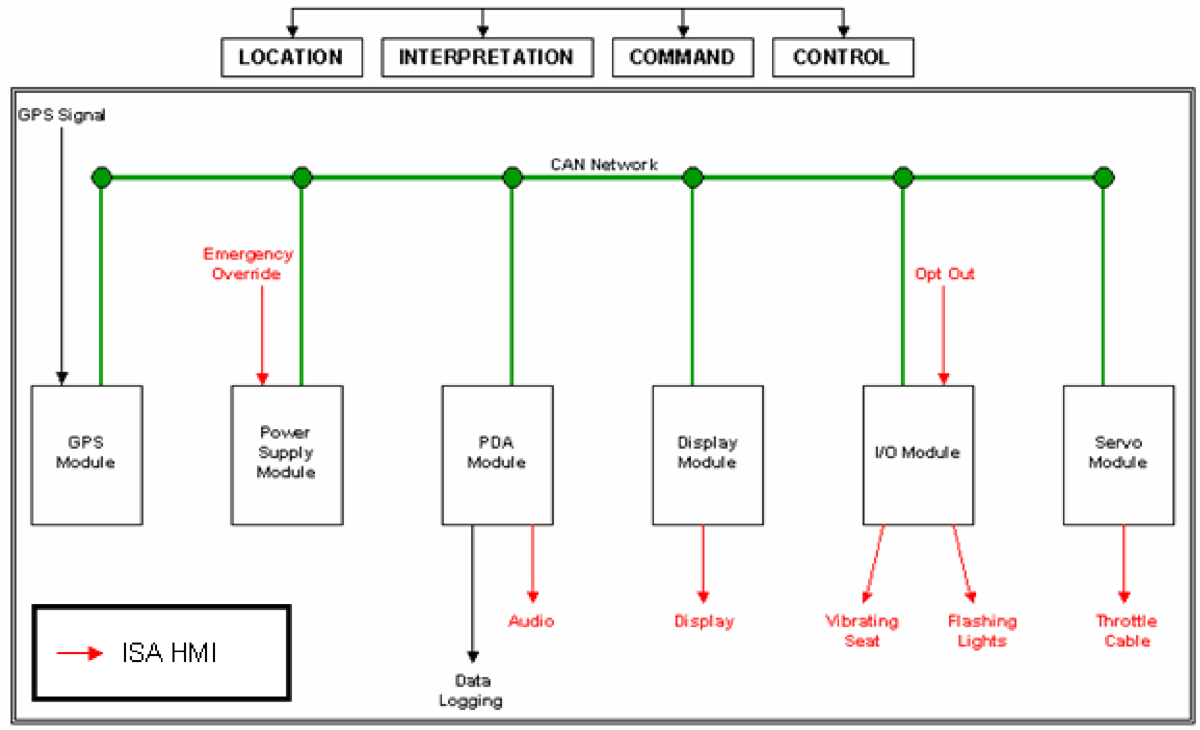


Figure 2: ISA motorcycle system diagram

2.6 Implementation

2.6.1 Location

The motorcycle's location, like that of the other ISA vehicles, was determined using a Global Positioning Satellite (GPS) system. The GPS receiver installed in the ISA motorcycle was an ordinary GPS receiver, similar to most of GPS receivers used for commercially available car navigation. The GPS satellite signals were detected by a GPS aerial and an associated GPS module determined the longitude, latitude, heading and speed of the bike. The information from the GPS module was transmitted via the CAN and could therefore be detected by all the system modules.

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. This was due to the trials of the ISA motorcycle taking place on a closed circuit on the MIRA Proving Ground which did not appear on the digital maps available to the project. Instead the system on the motorcycle used GPS "virtual beacons" to locate changes in speed limit. A "virtual beacon" is a circular zone of influence, of a given diameter, whose centre is defined by its latitude and longitude, as illustrated in Figure 3.

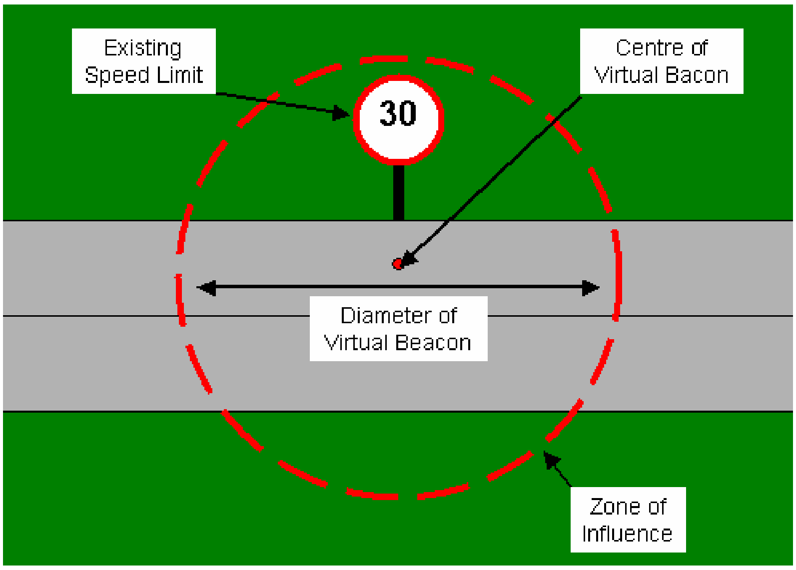
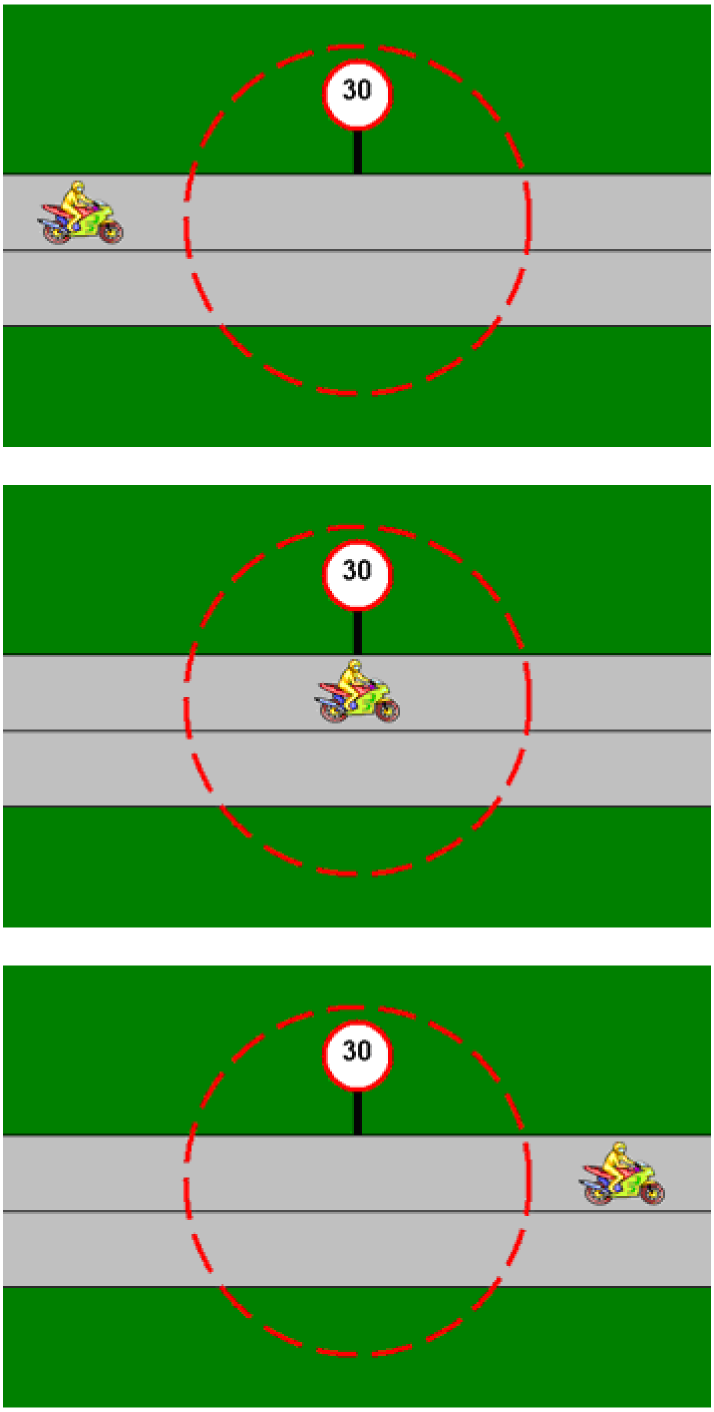


Figure 3: Illustration of a Virtual Beacon

Each virtual beacon had a designated speed limit that corresponds to a posted speed limit on the motorcycle's route. The PDA, within the PDA module, contained a look-aside table that defines the latitude and longitude, speed limit, heading (+/-10^{o}) and the name of each virtual beacon.

If the motorcycle's longitude and latitude were within the area defined by the virtual beacon's zone of influence and within the specified heading the beacon was said to be "true" and the system implemented the new speed limit. The ISA system continued to assume the last known speed limit is true until it passed through the next virtual beacon, as illustrated in Figure 4.



The motorcycle is travelling along the road approaching a new speed limit.

The motorcycle enters the virtual beacon and identifies the new speed limit.

The motorcycle is limited to 30 mph until it enters another virtual beacon with a different speed limit.

Figure 4: Identification of speed limits using Virtual Beacons

Because the ISA system fitted to the motorcycle used a virtual beacon system to identify the speed limits, it had no information about a new speed limit ahead of the vehicle until it entered the next true beacon and was therefore “unaware” what the future speed limit might be. This became apparent when the bike was travelling from a high speed limit to a low speed limit, or vice versa. For example, if a rider was travelling at 60 mph in a 60 mph speed limit and approached a 30 mph limit without the rider voluntarily slowing the vehicle down, the ISA system fitted to the motorcycle would only be able to intervene and reduce the vehicle’s speed once it was within the zone of influence of the new virtual beacon. The motorcycle would only start to decelerate as it entered the 30 mph limit and, therefore, would be travelling faster than the 30 mph for some time as it entered the new limit.

This issue highlights the importance of the virtual beacon's location. To reduce this overshooting of the speed limit, it was important to locate the beacons slightly before the speed limit sign, although the same effect could have been achieved by increasing the zone of influence of virtual beacon's with a large change in speed.

Another difference between the location system used on the ISA motorcycle and that used on the other ISA vehicles was the fact that the virtual beacon system relied solely on GPS. Unlike the other ISA systems, which also used map matching and dead reckoning to clarify the vehicle's location, the ISA system deployed on the motorcycle was more vulnerable to unreliability of the satellite signal caused by the topography of the area. However this was not a practical issue within the open test-track setting but might be if this approach was to be considered for other road environments such as that found in urban areas where interruption of satellite signal can occur. A GPS-based location system for an ISA motorcycle with on-board digital map, together with map-matching and dead reckoning could be developed as a commercial product.

2.6.2 Interpretation and command

Unlike the other ISA vehicles that had a sharp cut-off at the speed limit, the ISA motorcycle was designed to have a softer response to alleviate concerns about destabilising the vehicle. The underlying objectives of the ISA motorcycle system were to make the rider aware of the current speed limit, encourage the rider to maintain the speed limit but without the rider losing confidence in the ISA system. The values of the speed limits were set during the development phase with the test riders to meet the objectives. The response of the ISA motorcycle fell into three different phases:

- **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.

The speed at which the ISA motorcycle entered these phases was defined in a look-aside table on the PDA, as depicted in Table 2. The following scenarios are given as an example of how the system worked:

- If the motorcycle's speed was below the Warning threshold for the given speed limit, for example 53mph in a 50 mph zone, the ISA system would stay in the "Non-Intervention" phase.
- If the motorcycle's speed was above the Warning threshold but below the Intervention threshold, for example 56mph in a 50 mph zone, the motorcycle would enter the Warning phase.
- If the motorcycle's speed was above the Intervention Level, for example 60 mph in a 50 mph zone, the motorcycle would enter the Intervention phase.

Table 2: Threshold of activating Warning and Intervention phases on the ISA motorcycle

Speed Limit	Warning threshold	Intervention threshold
30 mph	32	36
40 mph	42	46
50 mph	54	58
60 mph	64	68
70 mph	74	78

When the PDA module on the ISA motorcycle recognised a true virtual beacon, it compared the actual vehicle speed to the speed limit for that beacon. Once it determined the appropriate phase (i.e. Non-Intervention, Warning, or Intervention), the PDA module published it onto the CAN bus. All the ISA motorcycle sub-system modules had the capability to receive messages on the CAN bus and were therefore aware of the appropriate phase. Individual modules then interpreted and commanded their own responses, depending on the phase of the ISA system.

The PDA also logged the longitude, latitude, heading, vehicle speed and beacon name at a rate of 10 Hz onto a local Secure Digital Memory Card. The data collected was used for research purposes only. It is worth nothing that the data collection undertaken in this trial is not a standard function of an ISA system.

2.6.3 Control

The ISA system on the motorcycle used a reduction in throttle demand to reduce engine power and therefore slow the vehicle down. Due to the relationship between forward momentum and lateral stability of a motorcycle, the ISA system did not control the motorcycle's braking system. Within the Servo module was a servo motor that was used to limit the motorcycle's throttle. The servo motor arm was connected to a cable that was attached to the throttle return link. The servo motor's range of motion was equivalent to the range of motion of the motorcycle twist grip. A schematic arrangement of the twist grip throttle, the carburettors and the ISA actuator is shown in Figure 5**Error! Reference source not found.**.

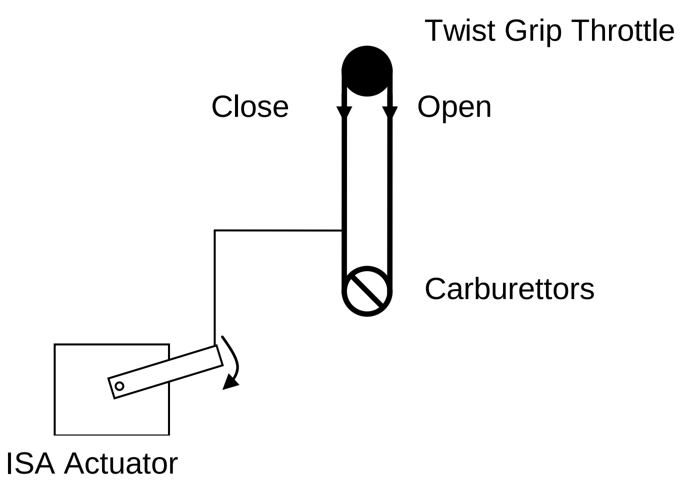


Figure 5: Schematic arrangement of the ISA actuator connection and the throttle

When the Intervention phase was triggered, the servo was activated and the motor arm rotated, over two seconds, through its range of motion. This rotation pulled the throttle return link back, closing the throttle and slowing the motorcycle down. As the throttle return link closed, the rider felt the twist grip close in their hand. The throttle then remained closed until motorcycle's speed was below the Warning threshold.

When the motorcycle was below the Warning threshold, the servo arm rotated back, over two seconds, through its range and the rider re-gained control of the throttle. The motorcycle then returned to the Non-Intervention phase.

2.6.4 ISA motorcycle HMI

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 (Figure 6) located directly in front of the rider mounted on the handlebars. This location was immediately next to the speedometer and the motorcycle's built-in information display and hence was considered to be an ideal position for this add-on ISA display with respect to minimal time that the rider has to glance away from the road ahead to read ISA information.

Figure 6: the ISA information screen

Additional visual indications were given by a pair of red LEDs fitted to the left and right hand upper edges of the motorcycle windshield, closer to the rider's line of sight. These were activated when the ISA system was activated and flashed

The change of speed limit (system status) was also indicated to the rider by **audio** alerts conveyed through earphones worn by the rider and connected to the ISA motorcycle system. These could deliver an audio alert signal initiated via a CAN bus message from the ISA system PDA processor. Audio alerts will probably be most useful at speeds of up to 50 mph. At higher speeds, the background noise is likely to mask the audio alerts.

A tactile display was also fitted to the motorcycle in the form of a vibration unit installed underneath the rider's seat. This was initiated in conjunction with other alerts as described above, to help notify the rider of a transition in ISA status and power control.

As described previously in Section 2.6.2, the ISA motorcycle differed from the other ISA vehicle systems because it had both an Intervention and a Warning phase. The ISA system employed on the motorcycle was designed to be “heavy persuasion, but mild intervention”, unlike the more strict speed control regimes employed on the other ISA vehicles. This means that the rider was repeatedly warned, using a variety of modalities, before any intervention took place. These warning strategies are described below.

During the **Warning** phase (i.e. when the vehicle is slightly above the speed limit), the following inputs were supplied 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 motorcycle’s speed significantly exceeded the posted speed limit, the **Intervention** phase was activated; the following inputs are 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 would have been reduced by the actuator.

The rider could activate a temporary exemption from ISA system control, or permanently disable the ISA system, by using the *Opt-Out* and *Emergency Disable* buttons (Figure 7), which had similar functionality to that realised on the ISA cars developed for this project.

Figure 7: The ISA motorcycle system elements

In terms of rider control, a pragmatic approach was adopted, rather than trying to produce an ISA motorcycle demonstrator that met all of the current Construction and Use regulations of a road-going motorcycle. For expediency, the horn button was reconfigured for the opt-out function, the headlight flash button was used for the Emergency Disable function, and the flashing lights were fitted in a position that was as close as possible to the rider’s forward field of view.

3. ASSESSMENT OF ISA FOR MOTORCYCLES

3.1 Trial requirement

The aims of the trials were to:
- assess the reactions of riders to the ISA system fitted to a current motorcycle,
- gauge their opinions and attitudes towards an ISA implementation on a motorcycle both before and after riding the test vehicle and
- make initial assessments on how their riding behaviour had been modified.

3.2 Methodology

3.2.1 Test site

In initial test planning, certain desirable features were identified for a preferred site for the ISA motorcycle trials. These included features such as road/track characteristics, trial management, logistics, access, safety and trial control.

In the context of road/track characteristics the test site should have the ability to replicate features encountered during urban and open road riding such as a variety of different speed limits, other road crossings and various types of road junctions. Other practical considerations included the ability to have controlled access to the site, for security and safety, and ease of trial management and control. Access to supporting facilities for rider trial briefings and post trial interview was needed.

The trial was also planned to be carried out in a controlled environment off the public roads. This was in part to address some of the considerations noted above, but also to take into account the prototype nature of the system and the relative unfamiliarity of the test riders to the system. Therefore, there was a need for a simple road environment with single user operation (i.e. no potential conflicts with other road users) and effective test environment control. Consequently the ISA motorcycle trial took place within a regulated test area rather than on the public road.

In relation to general trial logistics, a test site also had to be available for system development and refinement prior to the rider trials, and available at relatively short notice to accommodate weather and any other potential difficulties such as accommodation of changes to the trial participants' appointments. The trial programme was based on a total duration of 2 hours for each participant, giving a maximum of 4 participants in an 8 hour day. With a target number of 30-40 participants, this equated to 8 to 10 full days on the trial site. Potentially the test site needed to be available, for exclusive use, for at least two working weeks.

3.2.1.1 Test site review

As a result of this analysis, a number of potential test sites were investigated and individual features evaluated. These included a privately owned airfield, motor racing circuits, agricultural show grounds, and private test tracks.

3.2.1.2 Selected site

After reviewing the sites described, it was concluded that there was not a single site that provided an ideal combination of the identified features. However, the most appropriate facility considering the logistics, security and trial control aspects was one of the closed circuits within the MIRA Proving Ground, namely the MIRA Ride & Handling circuit. This was a closed circuit with an ability to arrange flexible booking and exclusive usage. To facilitate the ISA motorcycle trial, some temporary modifications to the basic track layout and facilities were added. This included the installation of speed limit signs having "limits" that had apparent validity to the road geometry and track layout, even within a simple track environment. As the track could not be permanently installed with such features, lightweight signs were fabricated to represent real road speed limit signs in design, layout and size, but that could be deployed within 10 minutes, enabling the circuit to be used for periods as short as a single 2 hour session.

Figure 8 shows the track that was selected. This particular test circuit was chosen because of its layout, which provided suitable locations for speed limit changes. The long straight stretch of track provided a good 60 mph section and the chicane area proved a suitable 30 mph area. This was where the trial marshals waited for the ISA motorcycle during each lap. A set of 30, 40, 50, and 60 mph speed limits were set up along the circuit. The diagram also shows the speed limits that were applied for the trials.

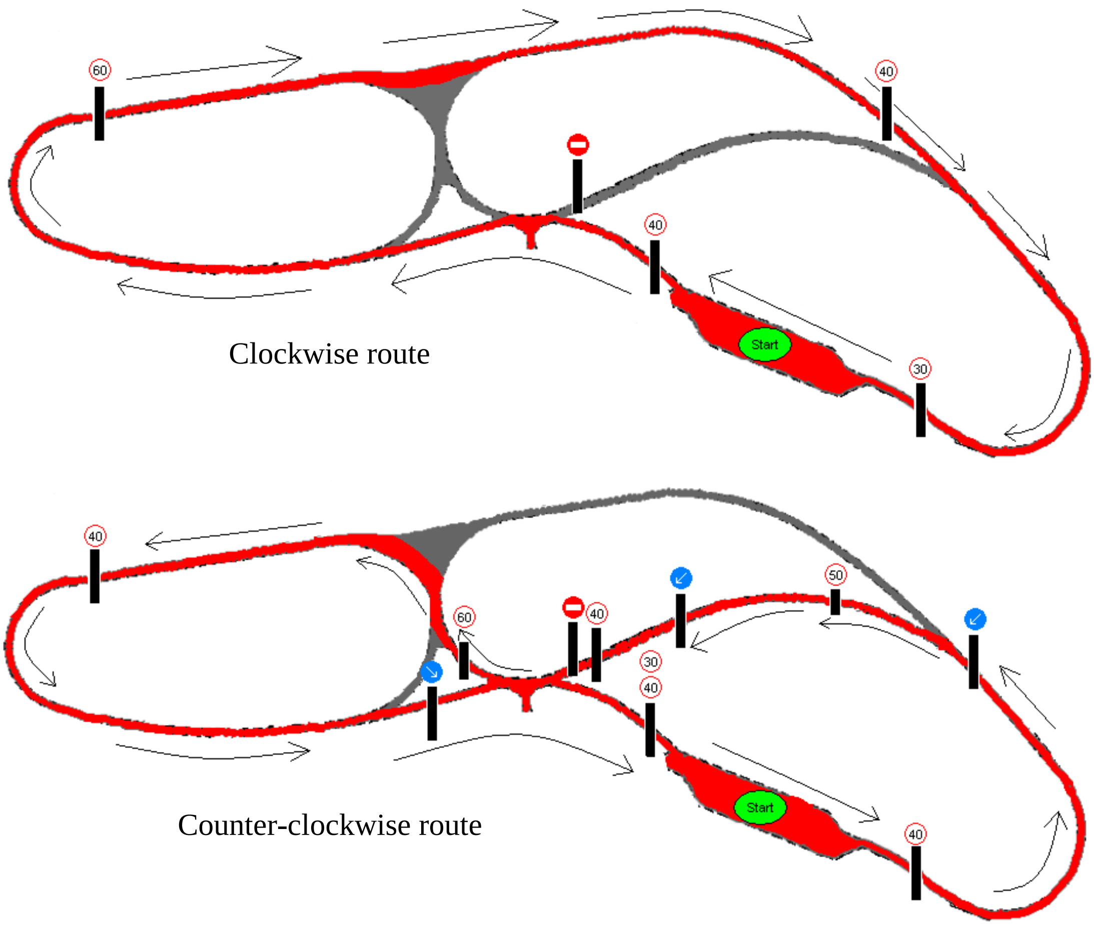


Figure 8: Test circuit used for ISA motorcycle trials

3.2.2 Trial protocol

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. The riders were asked not to use the ISA Opt-Out function.

Each participant was asked to ride the ISA motorcycle, following a pace car, around the MIRA access roads to gain experience of riding the ISA motorcycle. The ISA system was inactive and no data were logged during this period. The rider was then led to the test circuit. A pit-stop area was set up as a base for the ISA motorcycle to return after the series of laps.

Table 3: Trial Structure

Purpose	Description	Status of ISA	Provision of ISA function	Data logging
Familiarisation with test track	4 laps on test track behind a pace car (2 clockwise, 2 anti-clockwise)	OFF	N/A	NO
Baseline	6 laps on test track (3 clockwise, 3 anti-clockwise)	OFF	N/A	YES
Experience the **Advisory ISA system**	6 laps on test track (3 clockwise, 3 anti-clockwise)	ON (Advisory system)	Speed limit display & Warning	YES
Experience the **Assisting ISA system**	6 laps on test track (3 clockwise, 3 anti-clockwise)	ON (Assisting system)	Speed limit display, Warning & Intervention	YES
Experience the **Information system**	3 laps on access roads	ON (Information system)	Speed limit display & Warning	YES

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. The Information system provided the riders with travel information (e.g. upcoming traffic lights and junctions) in addition to all the functionality that an Advisory ISA system offers. This configuration was designed to investigate whether combining ISA with other rider information systems led to difference in riders' behaviour and acceptance of the ISA system. 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 were developed. Each rider was asked to complete a questionnaire before they arrived which comprised personal information (age, sex, and address), information about their personal experiences on a motorcycle, how often they rode, what they used a motorcycle for (for example recreation or commuting), how long they had held a motorcycle licence and what motorcycle they currently rode. The rider was also asked to complete a series of questions before, during and after they had experienced the Advisory and/or Assisting system, which collected their views on the ISA systems.

3.2.3 Participant selection

The aim was to include professional riders, members of rider groups and industry staff. Experienced and novice, male and female, and riders of different age groups were sought. All trial participants held the appropriate driving licence. To expedite the trials the first riders were drawn from the motorcycling community working at MIRA, though none of the participants whose results were recorded were involved in the development of the ISA motorcycle. Thirty-two invitations were also issued to a range of motorcyclists whose names were provided by the members of DfT's Advisory Group on Motorcycling. Due to cancellations, no professional riders participated by the end of the recruitment period. Upon completion of the trial, there were in total 33 participants, representing a range of rider characteristics including age, riding experience, and gender.

3.3 Results

3.3.1 Participant demographics and riding characteristics

Several questions sought information about key demographic and driving characteristics in order to give a brief overview of the riders taking part in the motorcycle trial. Thirty males (age range 32-60 years, M = 45.43, SD = 7.55) and three females (age range 26-42 years, M = 33.67, SD = 8.02) took part in the trial.

Sixty-one percent of the riders were married and 97 percent of riders had one or more children (under 18 years) living at their address. Based on occupation information, riders were classified according to the National Statistics Socio Economic Classification (NS-SEC) scheme. As Table 4 shows, the majority of riders held higher managerial or professional occupations. However, the participants recruited for this trial were not randomly selected, and therefore the sample characteristics presented here may not mirror the whole riding population, since understanding and appreciation of the system may vary across economic groups.

At the time of the trial, 31 out of 33 riders owned and rode a motorcycle. Riding experience varied across the riders (see Figure 9). On average, riders had 19.64 years (SD = 12.62) of riding experience and accrued an average annual mileage of 5612.50 miles (SD = 6250.82). The majority of riders (45%) had gained their licence via the practical test pre-1981 (see Figure 10). Six of the riders had gained their current licence via a direct or accelerated access course.

Table 4: National Statistics Socio Economic Classification (NS-SEC) of riders

NS-SEC Category	N	%
Higher managerial/professional	21	65.63
Lower managerial/professional	0	0.00
Intermediate occupations	1	3.12
Small employer/own account	10	31.25
Lower supervisory and technical occupations	0	0.00
Semi routine occupations	0	0.00
Routine occupations	0	0.00
Never worked/retired	0	0.00
Total	32	100.00

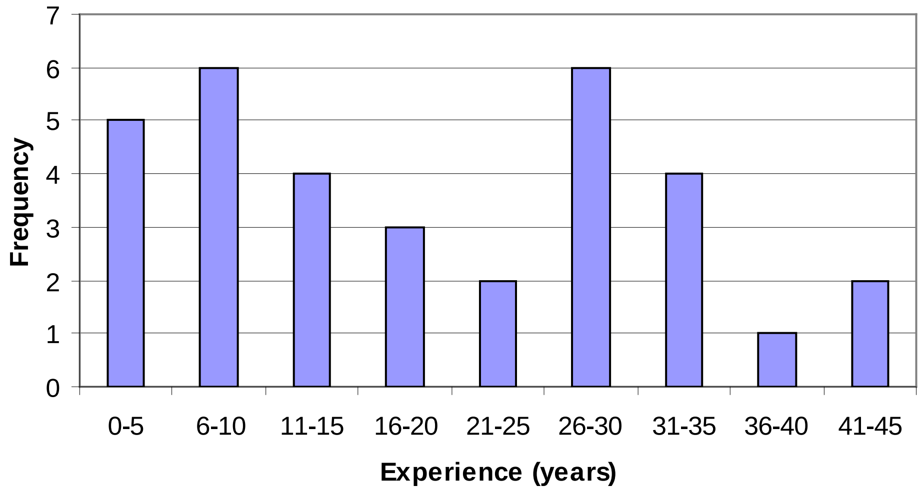


Figure 9: Riding experience (years)

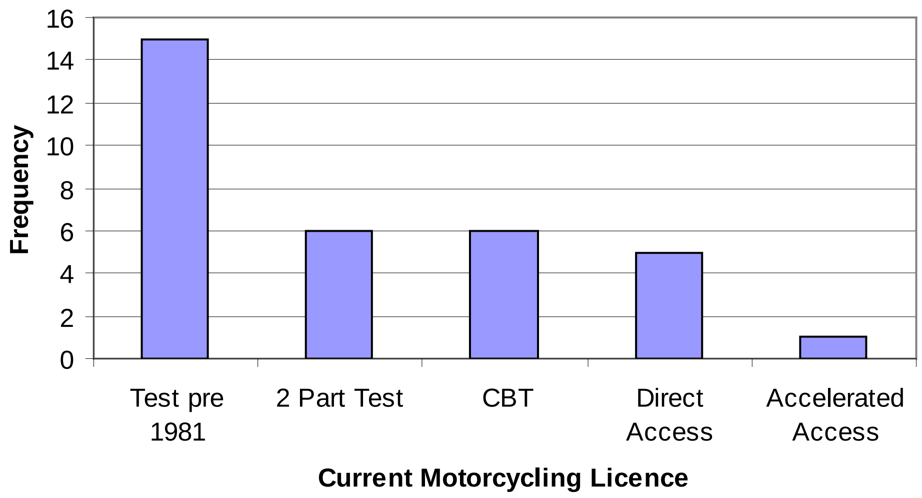


Figure 10: Method by which current motorcycling licence was acquired

Table 5 highlights that only one rider rode a motorcycle with an engine capacity less than 599cc. Since motorcyclists riding lower capacity machines are underrepresented, it is again difficult to make generalisations to the motorcycling population.

Table 5: Engine capacity of motorcycles owned

Engine Capacity (cc)	N	%
125	1	3.23
600-800	14	45.16
900+	15	48.39

Since higher capacity motorcycles can often have relatively little power (e.g. Harley Davidson) the classification given in Figure 11 provides greater insight into the 'types' of motorcycles currently owned. Sport/touring and super-sport machines appear most popular. Whilst the former tends to refer to larger engine machines with less power which are usually fitted with pillion passenger seating, the latter relates to some of the lightest and most powerful machines.

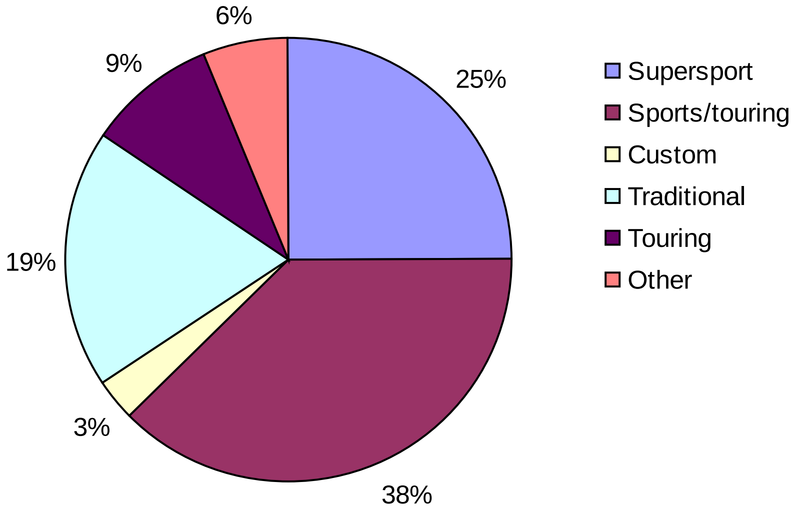


Figure 11: Types of motorcycle owned by participants

As can be seen in Table 6, seventy-five percent of the riders used their motorcycles for leisure purposes, with 36% of riders using their machine solely for this purpose. All riders possessed a driving licence and accrued an average car annual mileage of 12212.12 miles (SD = 7753.05).

Table 6: Purpose of the majority of trips made by participants

Purpose	**N**	**%**
Commuting/part of work	7	21.21
Leisure	12	36.36
Both	13	39.39
Other	1	3.03
Total	33	100.00

3.3.2 Analysis of questionnaire data

3.3.2.1 System acceptance

Questions sought to determine acceptability to the rider of the three systems tested. Rider acceptance was initially measured using an acceptability questionnaire for advanced telematics developed by Van der Laan, Heino and De Waard (1997). A copy of the questionnaire is given in Appendix 1. This measure allows system evaluations across the dimension of usefulness and satisfaction. The measure was administered before and after experience with the three systems.

As can be seen in Figure 12, riders' usefulness ratings of the ISA systems increased following experience with the ISA system. Statistical analysis demonstrated that riders rated the assisting system significantly higher following their test ride with the system (t(32) = -3.40, p<.01). Although a significant effect was not found for the advisory system (t(32) = -1.28, p = .211) the trends suggest that experience with an ISA system increased riders' perception of the usefulness of such a system. Surprisingly, riders seemed disappointed with the information system. Analysis revealed that riders' usefulness ratings for the information system significantly decreased following experience of the system (t(32) = 3.59, p<0.001). The system did not appear to live up to riders' expectations.

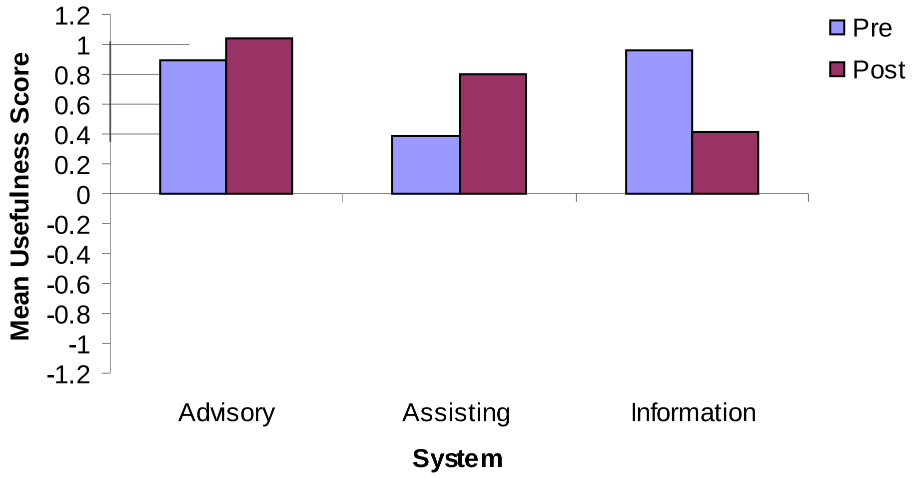


Figure 12: Acceptability rating for the dimension of "usefulness"

Comparisons *across* systems prior to experience highlighted a significant difference in ratings (F(2,64) = 9.31, p <.001). Post hoc analysis suggested that riders rated the assisting system significantly 'less useful' than the advisory and information system. However, following experience with each system, this significant difference was no longer apparent. Riders' ratings of the information system however were significantly lower than those for the advisory system (F(2,64) = 3.85, p <.001). Riders' satisfaction scores are as shown in Figure 13. It is interesting to note that riders were less satisfied with the advisory system following their test ride than they had originally expected (i.e. influenced by the definition of the three systems defined in the acceptability questionnaire) but more satisfied with the assisting system. The difference in ratings was not significant however. Riders' satisfaction with the information system was rated significantly lower following experience with the system (t(32) = 4.85, p<.001).

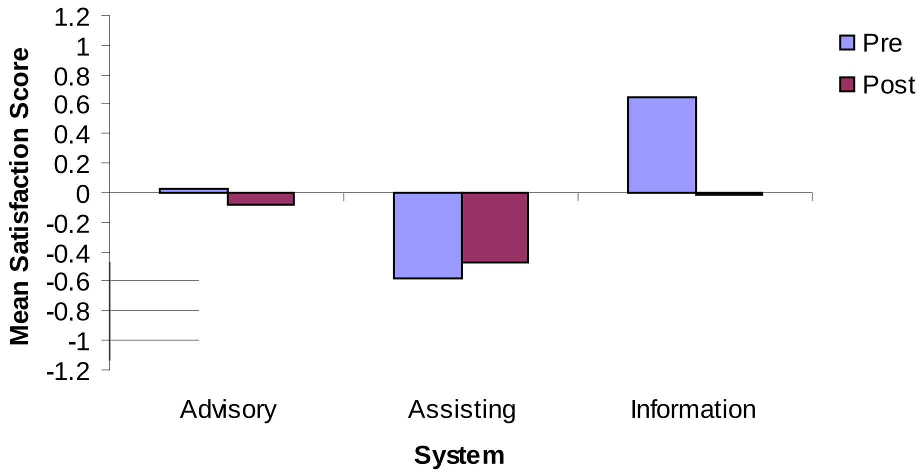


Figure 13: Acceptability rating for the dimension of "satisfaction"

Comparisons across systems, prior to experience, highlighted significant differences across ratings ($F(2,64) = 27.81$, $p<.001$). Post hoc analysis suggested that riders rated the assisting system significantly less satisfying than the advisory and information system and the advisory system less satisfying than the information system. These significant differences were still apparent following experience with each system ($F(2,64)= 5.39$, $p<.01$) except that rider's ratings of the information system were no longer significantly different to those for the advisory system. That is to say that the assisting system was significantly less satisfactory than the advisory and information system.

3.3.2.2 Riders' opinions about the ISA systems

Several sets of questions were designed to tap riders' opinions 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 14. Riders agreed that all the systems would increase traffic safety. There was no significant difference across systems however. 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. Repeated measures ANOVA confirmed that riders ratings of the level of irritation evoked by the systems were significantly different ($F(2,64) = 6.21$, $p<.01$). Post hoc analysis revealed that riders believed the assisting system was significantly more likely to increase irritation than the information system.

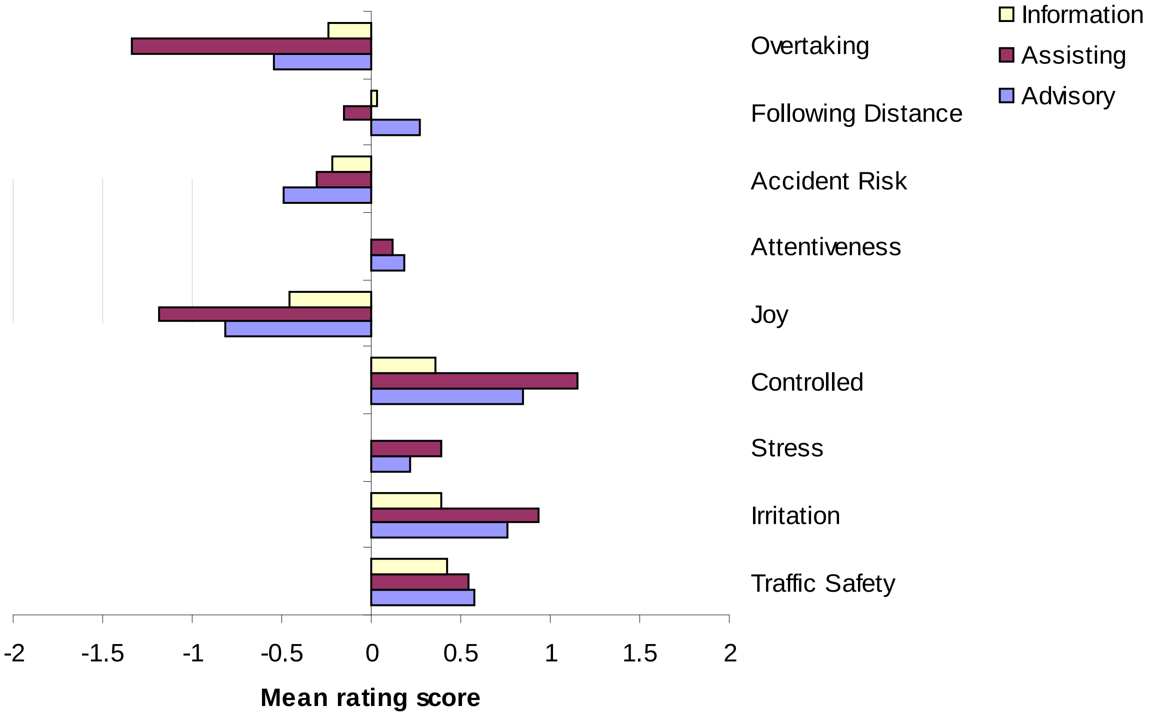


Figure 14: How do you think the following factor would change when riding the three systems compared to riding without any system on your motorcycle?

Riders also expressed significantly different responses regarding the level of control ($F(2,64) = 12.40$, $p<.001$) incurred by each system and the joy ($F(2,64) = 9.76$, $p<.001$) experienced when riding with these systems active. Post hoc analysis suggested that 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 also deemed as significantly more likely to decrease the joy of riding compared to the advisory and information systems. Although the differences across systems were non-significant, riders thought all the systems were likely to reduce the risk of an accident. It is interesting to note that the advisory system was believed to be more likely to reduce accident risk than the assisting system which curbed speeds. This is perhaps a reflection of riders' concerns regarding the safety implication of the assisting system (discussed further in Section 3.4). Riders also believed that the advisory and information system would increase following distances, whereas the assisting system would decrease distances. Differences across systems were again non significant however. A significant difference was found in drivers perceptions regarding overtaking behaviour ($F(2,64) = 19.85$, $p<.001$). Post hoc analysis revealed that riders believed overtaking would significantly decrease when riding with the assisting system compared to the advisory and information system.

The second set of questions investigated where and when the riders would use the three systems. As can be seen in Figure 15, riders were fairly reluctant to use the assisting ISA system in the majority of traffic conditions. Opposition to utilising the ISA systems seems strongest for those conditions that afford the greatest opportunity to speed (i.e. riding on rural roads, motorways, during off peak traffic). A number of significant differences in riders' appraisals of the systems utility were found. Ratings were significantly different for the potential use of the systems on rural roads ($F(2,64) = 11.04$, $p<.001$) with riders significantly more likely to use the information system more than the advisory and assisting ISA systems. Riders appeared unlikely to use the systems on the motorways ($F(2,64) = 10.58$, $p<.001$), during the daytime ($F(2,64) = 4.71$, $p<.05$) and in off peak traffic ($F(2,64) = 7.31$, $p<.001$) and the significant differences found suggest that they were less likely to use the assisting ISA system during these conditions than both the advisory and the information system. Riders believed that they would utilise all three system fairly often when riding in built up areas and in fog, and differences across systems were non-significant, suggesting they were of equal use.

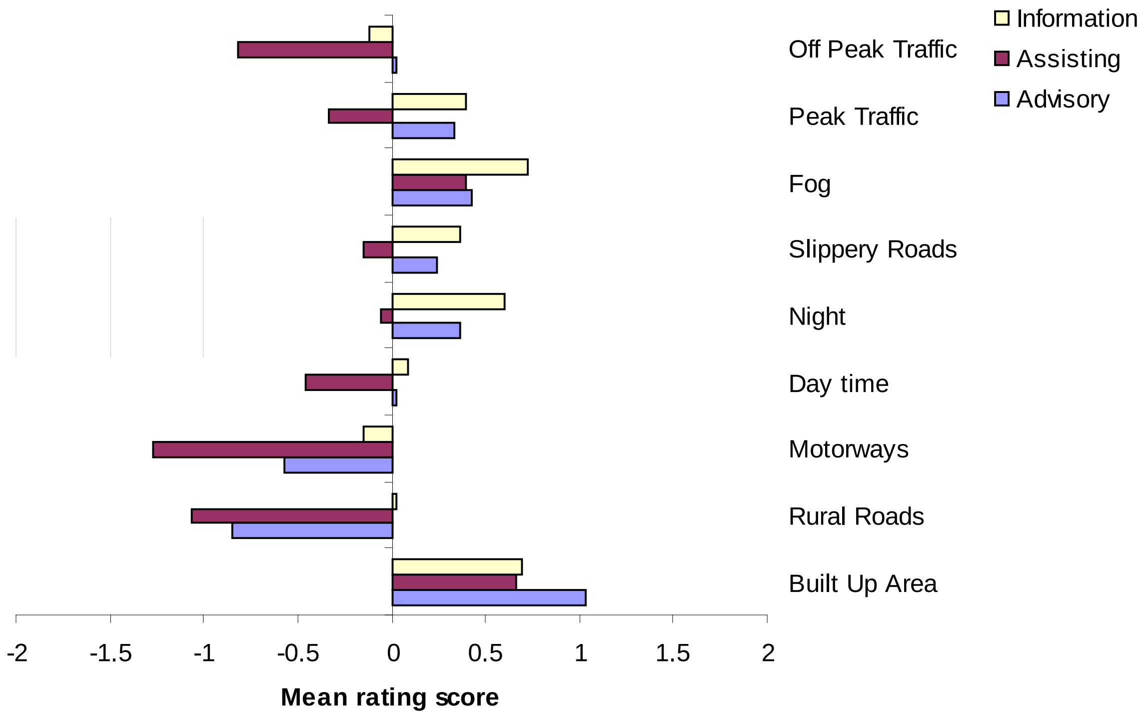


Figure 15: If you had this system on your motorcycles, where and when would you use it?

Patterns were also similar for riders' responses regarding their potential use of these systems when riding during the night, on slippery roads and in peak traffic. Examination of the means suggested that riders would make some use of the advisory and information system in these conditions, but saw little value in the assisting ISA system. Statistical analysis confirmed that riders believed they would use the three systems differently when riding during the night ($F(2,64) = 5.48$, $P<.01$), on slippery roads ($F(2,64) = 3.29$, $p<.05$) and in peak traffic ($F(24) = 4.13$, $p<.05$). Post hoc tests revealed that riders were less likely to use the assisting ISA system than the information system when driving at night, and less likely to use the assisting ISA system than the advisory system when riding during peak traffic hours. Post hoc analysis did not identify any significant differences for the slippery roads scenario.

The third set of questions explored for which rider groups the participants felt the systems were most justified. Figure 16 suggests that riders could not justify the imposition of any of the systems on private or professional riders. Significant differences found across the ratings for private riders ($F(2,64) = 6.25$, $p<.01$) suggested that the assisting ISA system was significantly less justifiable for this group than the advisory ISA and information system. Significant differences found across ratings for the justifiability of the three systems for professional ($F(2,64) = 4.52$, $p<.05$) and elderly riders ($F(2,64) = 5.16$, $p<.01$) suggested that the assisting ISA was significantly less justifiable than an advisory ISA system. ISA systems appeared most justifiable for young or novice riders and speed offenders. It was surprising to note that riders still believed an advisory ISA was more justifiable for speed offenders than an assisting ISA which would serve to limit repeat offenders' speeds.

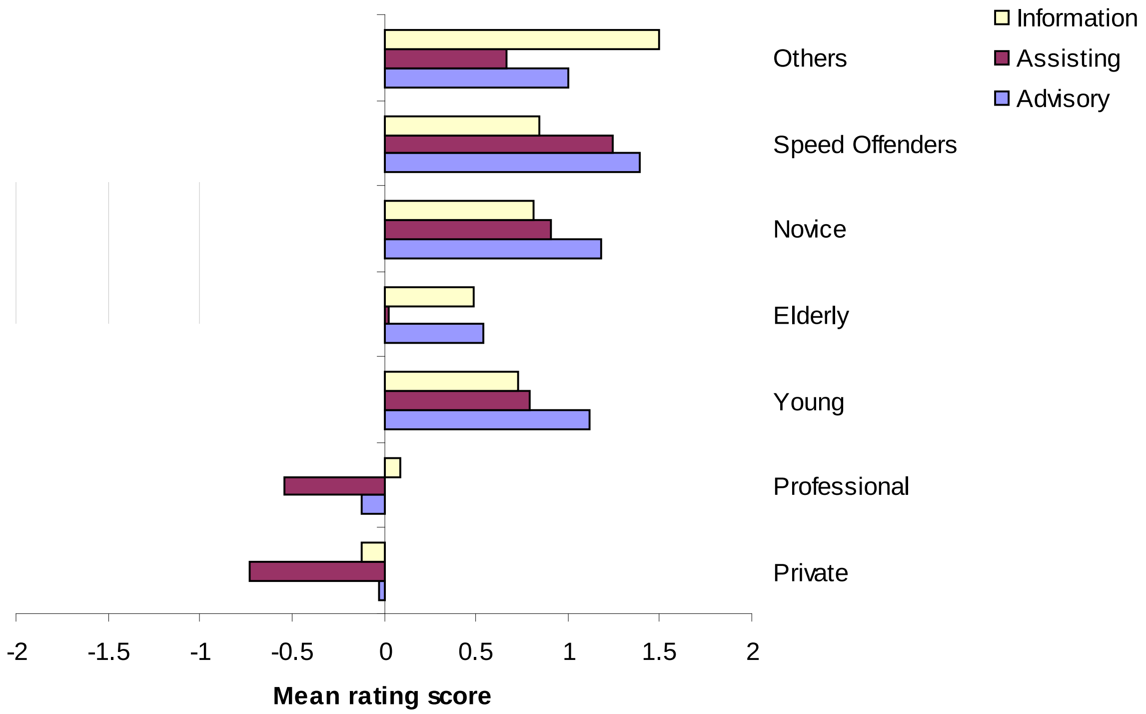


Figure 16: How justified do you think the system would be for the different categories of riders?

Measures of trust were also taken (Figure 17). The method used a pencil and paper scoring system in which participants marked their trust on a scale from 0 to 100 (Lee and Moray, 1992). Statistical analysis revealed a significant difference across riders' ratings ($F(2,64) = 6.027$, $p < .01$). Post hoc analysis revealed that riders' trust in the assisting system was significantly lower than their trust in the advisory system. Issues here may again relate to riders' safety concerns regarding reduced throttle input.

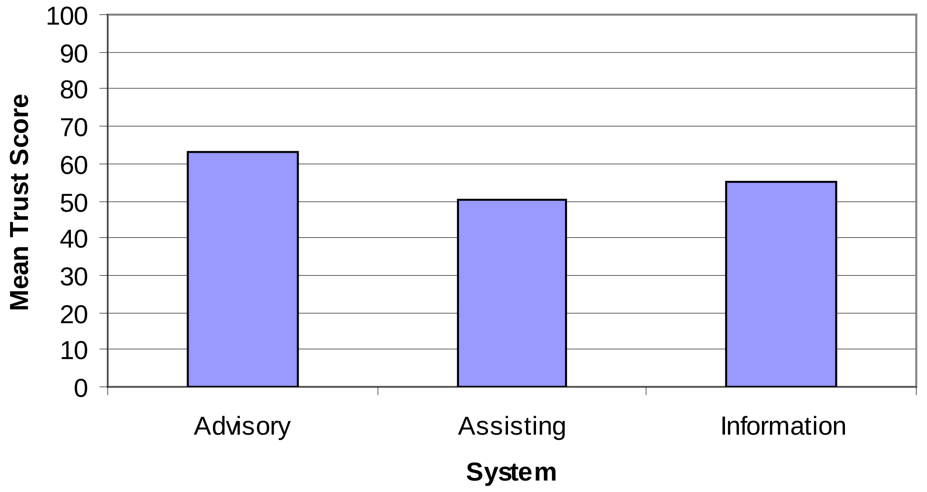


Figure 17: System trust ratings

Despite reservations expressed by riders in terms of the justifiability and potential utility of the ISA systems, Figure 18 suggests that 64% (of which 36% showed a definite interest) of riders were will willing to consider having an advisory ISA system fitted to their machine. Similarly 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 disappointing ratings regarding this system's acceptability. Here 70% of riders showed a willingness to have this system fitted, with 30% confirming a strong interest.

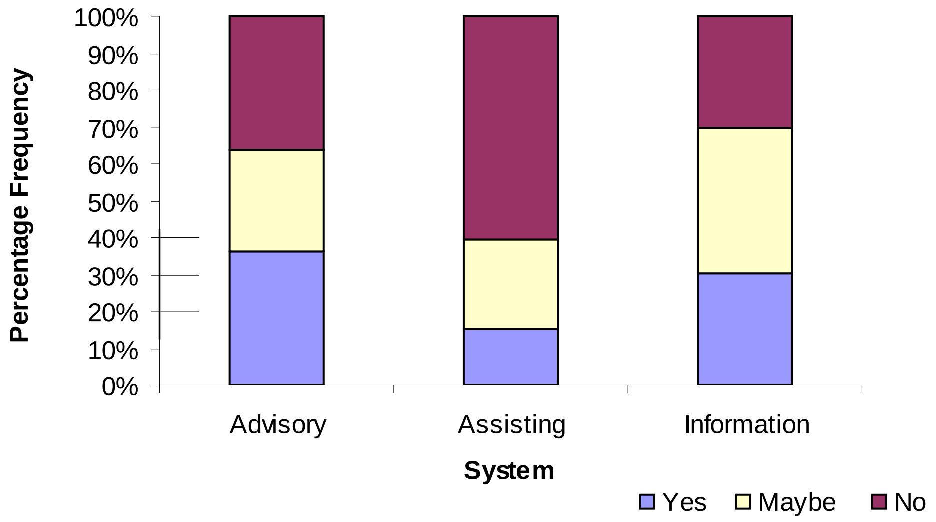


Figure 18: Willingness to install the systems

Figure 19 shows the responses of those riders who would consider having the systems installed on their motorcycle, which suggests that the riders were willing to pay between nothing and £300 for this equipment. An installation cost of £50-£100 was the most common price riders were willing to pay for the systems. Riders seemed to appreciate that the assisting ISA system would come at a higher premium given the technology associated with making this system viable.

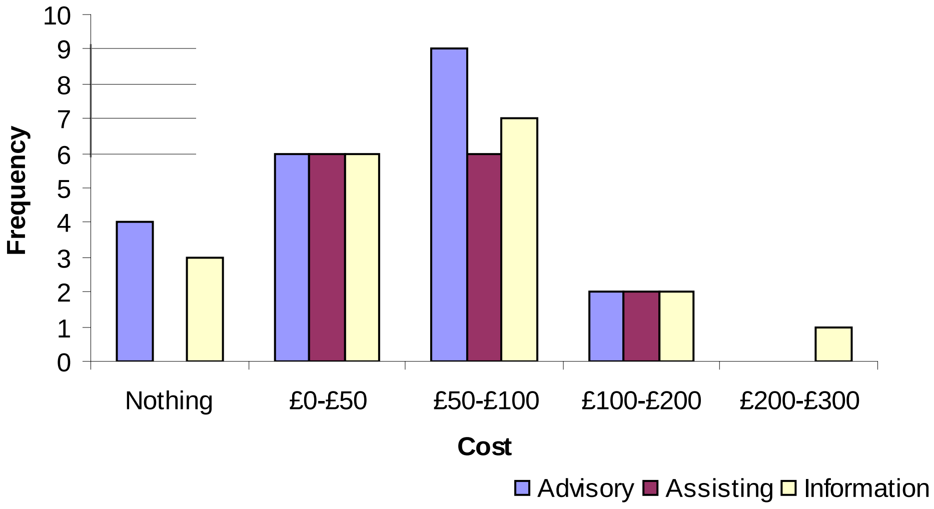


Figure 19: Willingness to pay for the systems

Those riders who did not express an interest in the systems were required to give explanations for their choice. Comments regarding the assisting ISA system suggested that riders felt the system was distracting and irritating:

"It's potentially distracting"
"You spend all the time being irritated instead of concentrating"
"It is annoying in certain circumstances"

Several concerns regarding control and safety were also raised:

"I'm worried about reducing the safety of reducing power"
"If the rider doesn't have complete control it might be dangerous"
"You feel controlled. If you were in a dangerous situation you don't want to push a button"

For others the system simply took the enjoyment out of riding:

"*I ride for pleasure; it would take the fun away from riding"*

Comments from those who would be unwilling to install an advisory system also included feelings of control despite the imposition of any system intervention:

"Even though it's advisory it's still a feeling of control. It messes up your natural driving style"
"These devices take control and responsibility from the rider. I felt controlled"

Again the system was seen as irritating and taking the fun out of riding:

"Quite annoying"
"It detracted from the pleasure and made me more conscientious of the speed. It was irritating. I found myself irritated but didn't hate it"

In general, reasons given by those not willing to install an information system focused on distraction, irritation and HMI issues:

"Tends to overload riders with information in a built up area"
"It would depend on how much information is given; every junction etc is irritating and largely useless but hidden junctions etc would be good"
"Your eyes should be on the road – poor visibility of information in sunlight"
"Perhaps if display was easier to see it would be more useful in built up areas. I have to move my head to see it"
"Only if it had beeps and not the other physical warnings"
"the system needs to be more sophisticated giving paths through complex junctions and indicate rights of way""

When comparing responses across riders reluctant to install the three systems, it is encouraging to note that a great deal of the concerns relate to HMI issues or irritation which may well be counteracted with a more sophisticated design and greater exploration of the warning signals most amenable to riders. The *perceptions* of control and reduced safety are considerably more difficult to address and remain a continuing issue for ISA across all vehicles.

3.3.3 Analysis of logged vehicle data

As reported in Section 3.2.3, participants were recruited by invitations to selected riders rather than by pre-defined demographic characteristics (as adopted in the car trials), analyses of logged vehicle data were therefore carried out by categorising participants with respect to their actual riding behaviour on the test track during the trial (i.e. post-hoc). As a result, participants were grouped into three categories:

- Cautious Riders: participants with a smooth riding style. They obeyed the posted speed limits and maintained a similar speed profile throughout the different phases of the trial. The ISA system did not appear to affect their riding style.
- Tester Riders: participants who were initially cautious and usually obeyed the posted speed limits on the test circuit during the baseline run. They then increased their speed and tested the system during the Advisory and Assisting ISA phases.
- Aggressive Riders: participants who attempted to exceed the speed limit at all stages of the trial. However, their top speed was curtailed when Assisting ISA was activated.

Table 7 depicts statistics of a Cautious Rider's speed data, which suggests that the speed data collected from the three trial phases were remarkably similar; i.e. the presence of ISA did not influence the rider's behaviour.

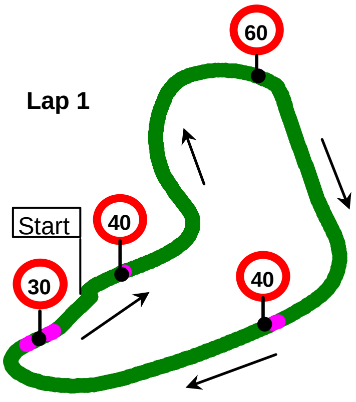
Table 7: Key statistics of the Cautious Rider's speed data

	Baseline	Advisory ISA	Assisting ISA
Mean speed (mph)	38.4	37.7	38.5
Standard Deviation	10.0	11.0	10.3
Maximum speed (mph)	56.0	58.0	57.0
Coefficient of Variation of speed	0.26	0.29	0.27
Percentage of travel distance over speed limit	1%	<1%	2%
Percentage of travel time over speed limit	1%	<1%	2%

Figure 20 illustrates the Cautious Rider's choice of speed on three continuous laps along the course of the test track. The participants started by joining the test track from the pit stop area (i.e. the beginning of Lap 1), carried onto Lap 2 without stopping, and then finished by pulling up to the pit stop area upon completing the third lap. Figure 20 suggests that the participant hardly exceeded the speed limit and that ISA system had virtually no effect on his riding speed. This pattern is further confirmed by Figure 21 which illustrates that the speed profiles of this participant derived from the three trial phases are very similar.

Within speed limit	Over speed limit

Baseline



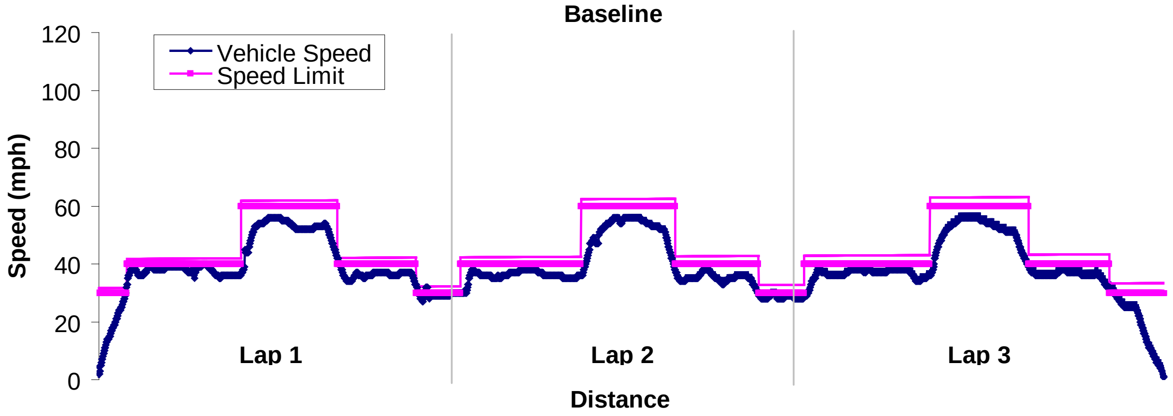

Baseline
Vehicle Speed
Speed Limit
Speed (mph)
120
100
80
60
40
20
0
Lap 1
Lap 2
Lap 3
Distance

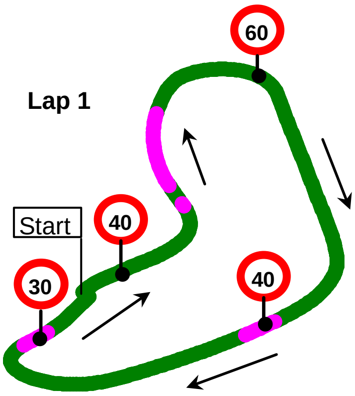
Table 8 depicts statistics of a Tester Rider's speed data. The participant demonstrated distinctively different riding behaviour between the baseline and when ISA was activated. This is considered to be due to a novelty effect (i.e. the participant was experimenting to find out how the ISA systems worked) rather than the participant intending to break the speed limit. This 'testing' pattern is also illustrated in Figure 22 and Figure 23. It is worth noting that the presence of Assisting ISA clearly led to diminished speeding violation, as shown in Table 8.

Table 8: Key statistics of the Tester Riders' speed data

	Baseline	Advisory ISA	Assisting ISA
Mean speed (mph)	38.5	40.0	39.1
Standard Deviation	9.4	12.1	11.6
Maximum speed (mph)	59.0	77.0	77.0
Coefficient of Variation of speed	0.24	0.30	0.30
Percentage of travel distance over speed limit	9%	29%	19%
Percentage of travel time over speed limit	9%	19%	16%

Within speed limit	Over speed limit

Baseline



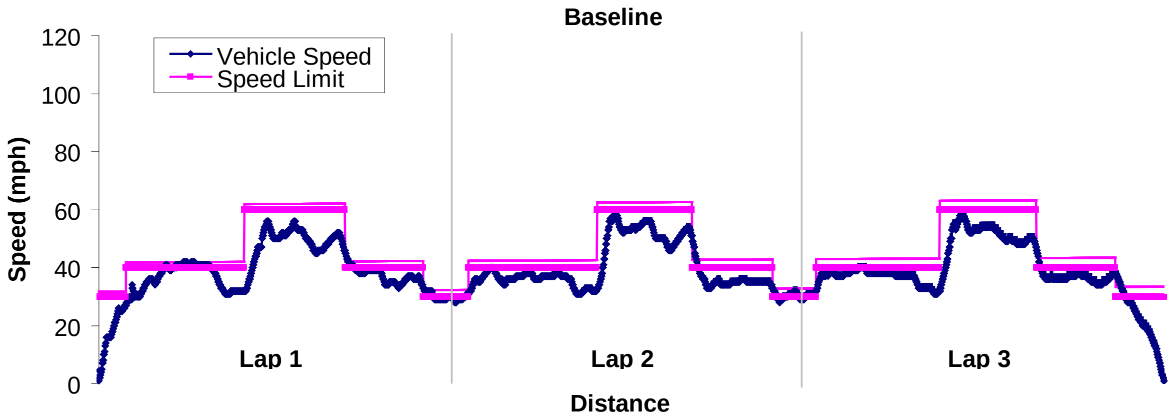

Baseline
Vehicle Speed
Speed Limit
Speed (mph)
120
100
80
60
40
20
0
Lap 1
Lap 2
Lap 3
Distance

Table 9 depicts statistics of an Aggressive Rider's speed data, which suggests that the speed data collected from the baseline and when Advisory ISA was activated were similar but the presence of Assisting ISA led to diminished speeding violation (i.e. particularly the maximum speed) as well as reduced speed variation (i.e. Standard Deviation and Coefficient of Variance).

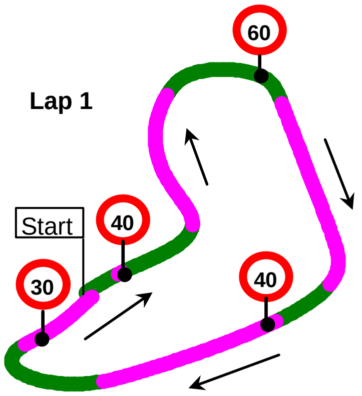
Table 9: Key statistics of the Aggressive Rider's speed data

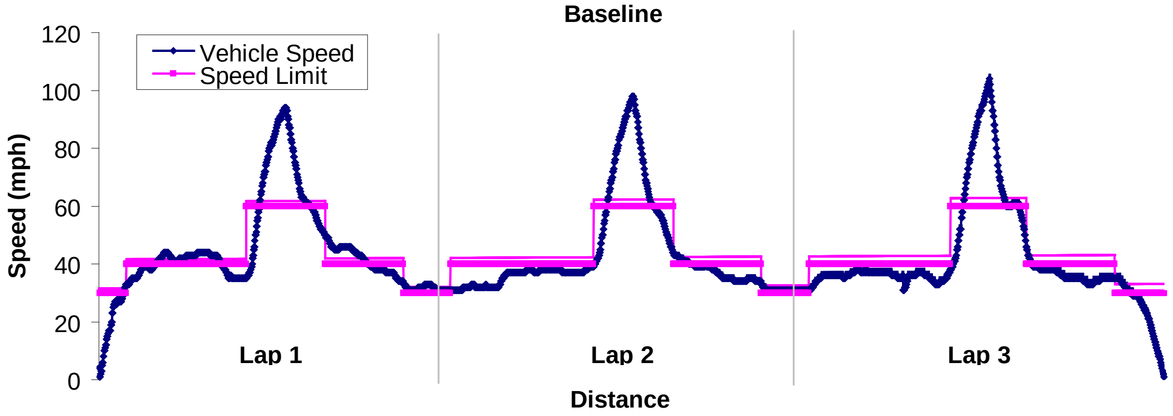
	Baseline	Advisory ISA	Assisting ISA
Mean speed (mph)	42.6	43.9	43.4
Standard Deviation	16.9	16.6	12.9
Maximum speed (mph)	104.0	104.0	91.0
Coefficient of Variation of speed	0.40	0.38	0.30
Percentage of travel distance over speed limit	44%	50%	50%
Percentage of travel time over speed limit	35%	41%	45%

Figure 24 compares the choice of speed along the test track from the Aggressive Rider, which demonstrates that the participant attempted to exceed the speed limit most of the time, especially on straight sections of the test track. The speed profiles shown in Figure 25 confirm that Advisory ISA had little effect on the Aggressive Rider's choice of speed but Assisting ISA had a pronounced effect in correcting excessive speeding.

Within speed limit	Over speed limit

Baseline




Baseline
120
100
80
60
40
20
0
Speed (mph)
Vehicle Speed
Speed Limit
Lap 1
Lap 2
Lap 3
Distance

3.4 Discussion

3.4.1 Attitudinal changes

Acceptability measures suggested that experience with the assisting ISA system significantly improved riders' appreciation of the usefulness of the system such that any significant differences in evaluations across systems were no longer apparent. In terms of satisfaction however, the assisting ISA system was rated significantly lower than both the advisory and information system. This would tend to suggest that, although riders could see the potential benefit of the system, they did not feel comfortable with either the intent of the system or the manner in which it operated. Comments from those opposed to installing the system suggested that they felt the system was in many ways distracting and irritating. Whilst one rider liked that the system curbed his acceleration to the next limit, others expressed safety concerns regarding the closure of the throttle on corners, reduced power and the need to push buttons if found in a dangerous situation. Indeed, riders placed least trust in this system when questioned. For others the system simply took the enjoyment out of riding, and comparisons across the three systems revealed that riders felt that the assisting system would decrease the joy of riding significantly more than an advisory or information system. There was a general reluctance to make use of the assisting ISA in the traffic scenarios depicted when compared to the other systems, and riders felt there was little justification for the enforcement of assisting ISA across different rider groups. Opposition was so strong that riders still believed an advisory ISA was more justifiable for riders that incurred speeding offences than an assisting ISA which would serve to limit repeat offenders' speeds.

Riders' evaluation of the Advisory system did not differ significantly following experience with the system. Trends would suggest that riders tended to rate the system higher in terms of usefulness but lower in terms of satisfaction following system use. Comments from those opposed to installing the Advisory system again highlighted riders' irritation with the system and whilst they appreciated that the system did not control their speed some riders still felt as if they were being controlled by a system. Concerns mentioned also included the system taking responsibility from the riders and system reliance (i.e. one rider expressed that the system made them lazy as they did not look at the speedometer), which are in agreement with the concept of locus of control (Rotter and Hochreich, 1975). Since the majority of riders engage in some level of leisure riding (i.e. Table 6), which is in fact consistent with the literature (e.g. Chorlton and Jamson, 2003), the system was seen to decrease the joy of riding.

Comparisons across the Advisory and Information system perhaps provide greater insight in riders' evaluations and acceptability of ISA systems. Within this study the information system reflected an advisory ISA system with additional information relating to road environment (e.g. junctions). It has been suggested that acceptability of ISA systems may be improved when integrated with other more 'appealing' systems. Marchau, and Heijden and Molin (2005) identified that individuals' willingness to pay for ISA was not only related to its functionality in terms of the level of control it exerts on differing road types but also the additional systems incorporated. The results from ISA car trials (Lai, Chorlton, and Carsten, 2007) have suggested that experience increases acceptance of ISA; thus a multi-functional platform could provide an ideal opportunity for riders to try this technology. Comparisons across the acceptability measures, however, suggest that experience with the information system significantly decreased riders' appreciation of the usefulness of the system and their satisfaction with the system. Given that usefulness ratings were significantly lower for the information system compared to the advisory system, results suggest that combining functions within one technology platform may not necessarily promote acceptance of a potentially controversial system. In general, reasons given by those not willing to install an information system focused on distraction, irritation and HMI issues.

Some riders commented that the additional visual messages relating to junctions etc. distracted their visual attention from the road and overloaded the rider with information within built-up areas. Others found the warning irritating, particularly when the system provided relatively obvious and useless information. Whilst these certainly suggest that the nature of the system itself is unappealing, comments regarding HMI problems make it difficult to determine whether riders' opposition to the system would be sustained if the system was part of the motorcycle's original fittings. For example, riders commented that the screen was inappropriately positioned and visibility was poor in sun-light.

Whilst the above criticisms hold true for all the ISA system, it is particularly case for the Information system, which by their nature (i.e. identifying of every junction etc) attract riders' attention considerably more. Therefore, for this system, HMI may play more of role in determining riders' satisfaction. It is therefore difficult to determine the exact nature of riders' discontent with the system and unfair to assume that the system itself (rather than the HMI) was disliked. Indeed, riders tended to report more favourable attitudes towards the use and justifiability of the Information system compared to the Advisory system, despite the imposition of the same functionality of ISA. Moreover, the feeling of being controlled was rated as significantly less than that for the advisory system. Again, however, since the access road used within the information ride did not contain a speed limit change, the riders were much less likely to interact with the speed limiting function compared with their advisory ISA ride and it would be biased to assume that riders were fully aware of the speed advice function provided by the Information system.

Results here indicate some promise for 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. Results were disappointing for the Information system. However, whilst acceptance measures showed a drop in riders' evaluations, the additional measures suggested that riders would, on the whole make more use of this system than any other in the traffic scenarios listed.

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. For those not willing to have the systems installed it was encouraging to note that a number of their concerns could be addressed within the design of the system.

3.4.2 Behavioural changes

The Advisory ISA system seemed to provide little effect on participants' choice of speed. In contrast, the Assisting ISA system appeared to have demonstrated a more prominent effect on curtailing excessive speed. However, the limited time that each rider was able to experience the ISA systems did not provide sufficient data for assessing statistical significance of changes in riding behaviour. It is worth emphasising that the purpose of this trial was primarily 'proof of concept'. Extended trials on public roads (where natural traffic is present) over a reasonable period of time (e.g. several months, as used for the ISA cars) would be required for behavioural changes to be robustly assessed.

While the small sample size prevents firm conclusions from being drawn, it should be noted that none of the 33 participants expressed concern regarding the motorcycle's stability being affected by the presence of an ISA system. This is an often reported comment (i.e. such as 'ISA is unsafe') concerning proposed ISA motorcycle systems. Considering that the Assisting ISA system reduced the maximum speeds achieved by the riders with an Aggressive riding style and curtailed the speed excursions above the specified limits, this encourages further research for the development of an ISA system widely acceptable to the motorcycle community.

4. DISCUSSION

The application of ISA to the passenger car user has been the subject to a growing body of research at a national and international level. Other parts of this project have extended this base of knowledge, by examining how drivers changed their attitudes to the ISA concept and adapted their speed-related behaviour when experiencing a system over a length of time in real road conditions.

A smaller more focused body of research has concentrated on the real world experience of drivers of commercial vehicles, both passenger service vehicles and goods vehicles, with ISA functionality. This project has also added to this understanding of reactions to ISA amongst professional drivers operating within the context of a more regulated driving environment and regime.

However the impact of an ISA functionality on motorcycle users is at a relatively early stage. The work carried out within this project has taken a necessary first step in trying to establish whether there is potential validity in extending a rider assistance system such as ISA into the motorcycle domain. It has also conducted some initial assessments of rider reaction.

When developing a new and as yet untried vehicle system, it is normal to evaluate it first within the controlled environment of an off-road test track where appropriate control of trials can be conducted and the performance of a new feature evaluated in controlled conditions. In this respect the ISA motorcycle concept development, design, implementation and trial format has allowed evaluation of a functioning system to be carried out by a range of experienced riders under synthetic road conditions.

The design and implementation of the functional aspects of the ISA system fitted to the motorcycle described above has taken note of the experience gathered in system development in other parts of ISA research both within the UK and other countries. However the typical vehicle characteristics, operating performance, rider characteristics, vehicle dynamics and rider expectations for the motorcycle have had to be considered in depth before making decisions on how ISA would function and interact with the rider prior to trialling with the test riders. Some of this analysis has been logical (i.e. a consideration of what can be implemented on a test vehicle), some has been logistical (i.e. providing functionality within a defined and limited trial context), some has been technical (i.e. the ability to provide a robust and reliable retrofit solution suitable for trials) and some has been user-centred (i.e. the ability to provide a multi-mode interface to the rider to deliver alerts of system intervention).

Overall the system design and implementation selected provided an appropriate level of functionality to enable the trials to be completed reliably and safely. However it must be recognised that the system design applied here had of necessity to make certain choices as regards the general approach and that it was not possible, within the context of this project, to systematically evaluate all the possible design approaches. Some of the feedback received from the trial participants reflects this position. Comments concerning further alteration, refinement or deletion of aspects of how ISA was enabled on the motorcycle utilised in the trials indicate a divergence of opinion amongst the riders, but also stem from the fact that the motorcycle was retro-fitted in what was in effect a proof of concept ISA system rather than a fully developed product fully integrated into the design of the motorcycle.

Assisting and Information system functionality is noted. The higher acceptability of the Advisory system where no intervention occurs is perhaps unsurprising, especially when a degree of doubt existed among the trial riders as to whether an assisting (i.e. speed controlling) system would have adverse affects on vehicle dynamics in some scenarios. However it is also noted that such more intrusive ISA functionality is thought to have higher applicability to perceived vulnerable motorcycle users such as the young and novice riders and to speed offenders.

The trial results also seem to indicate that the evaluation of a novel concept such as ISA on a motorcycle seems to evoke a range of responses depending on prior attitudes and behaviours. The distinction between “Cautious”, “Tester” and “Aggressive” rider is a simple categorisation of the motorcycle data collected. In many ways this may be seen as simplistic but does suggest that different inherent behaviours, attitudes and reactions are elicited in a short-term evaluation of a novel feature such as ISA within a synthetic road environment. This may have an implication on the consideration of how concept evaluation evolves through truly synthetic environments (such as simulation) to confined track trials, to real road environments. In this context the ISA motorcycle evaluation is only at a formative phase.

Finally there is the aspect of rider attitudes to rider assistance technologies such as ISA. Motorcycles have significant differences to other road vehicles: high power-to-weight ratios (and therefore accelerative and vehicle dynamics performance), less isolated/protected operator environments, less constrained manoeuvring interaction with other road users within traffic. There are specific rider expectations and usage patterns concerning what a motorcycle offers in comparison to other road vehicles. In this latter aspect it is perhaps the motivational aspects of motorcycle ownership that offers the biggest challenge to the design and introduction scenarios to a motorcycle ISA, or other supporting technological applications that perhaps offer the biggest challenge. As recorded comments describe:

“I ride for pleasure; it would take the fun away from riding”
“Even though it’s advisory it’s still a feeling of control. It messes up your natural driving style”
“These devices take control and responsibility from the rider. I felt controlled”

Balanced against these are the comments related to relative acceptability of application of such functions to perceived “risk” categories such as young novice riders.

It would seem that the gap between user acceptance of technologies, such as that being developed and marketed to the passenger car market, and those applied to the motorcycle have yet to be investigated. The appreciation of users to the future road traffic environments, new assistive technologies and their evaluation of potential for application and acceptability in changing future road usage and management remains to be addressed. In particular, ISA, as a means for delivering future road accident reduction benefits through driver/rider speed compliance, is only one facet of a wide debate where other rider support technologies may be considered.

5. CONCLUSIONS

Adapting ISA to a motorcycle environment is a 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. An ISA motorcycle demonstration platform has been realised that has offered a safe and effective vehicle demonstrator to enable proof-of-concept assessment trials. A trial site, format and rider selection process was defined to enable an evaluation exercise to be performed safely. A group of experienced motorcycle users was selected for an initial assessment trial in which pre/post attitudes and rider characteristics were evaluated and riding behaviour data was collected.

In terms of attitudes, perceptions of usefulness increased after experience of the ISA functionality in comparison to opinions expressed before exposure to ISA. However, satisfaction ratings were more varied with the Assisting ISA systems being judged significantly less satisfactory than the Advisory ISA or the Information system. Attitudes regarding the impact of ISA on riding indicated negative perceptions to “Joy”, “Overtaking” and “Accident Risk”. However, a positive perception to “Traffic safety” suggests that ISA has aspects that counterbalance these negative responses.

Overall, this ISA motorcycle trial has identified that there is a possible disjuncture between on the one hand the technical possibilities with concepts such as ISA and on the other hand the perceptions and attitudes of the current users of motorcycles. This may be because little emphasis has been placed upon how new assistive technologies pioneered in the passenger car and commercial field may migrate into the motorcycle sector and have an impact upon the perceived and actual safety, efficiency and marketability of motorcycles. It may also be influenced by the perceptions of motorcycle users with regard to the advantages or positive features of these vehicles, where the “freedom” and “independence” aspects of riding are valued highly by users and advisory and/or assisting technologies are perceived to be negative factors.

6. REFERENCES

Carsten, O.M.J. and Tate, F.N. (2000). Final report: Integration. The External Vehicle Speed Control project. Institute for Transport Studies, University of Leeds, Leeds.

Chorlton, K. and Jamson, S.L. (2003). Motorcycle ownership: riders' characteristics and patterns of use. Deliverable 3 to the DfT Contract No. 9/31/64. Institute for Transport Studies, University of Leeds, Leeds.

Lai, F., Chorlton, K. and Carsten, O. (2007). Overall Field Trial Results. The ISA-UK project. February, 2007. Institute for Transport Studies, University of Leeds, Leeds.

Lee, J. and Moray, N. (1992). Trust, control strategies, and allocation of function in human-machine systems. Ergonomics, 35(10), 1243-1270.

Marchau, V.A.W.J., van der Heijden, R.E.C.M. and Molin, E.J.E. (2005). Desirability of advanced driver assistance from road safety perspective: the case of ISA. Safety Science, 43, 11-27.

Rotter, J.B. and Hochreich, D.J. (1975). Personality. Glenview, Illinois: Scott, Foresman and Company.

Van der Laan, J.D., Heino, A. and De Waard, D. (1997). A simple procedure for the assessment of acceptance of Advanced Transport Telematics. Transportation Research Part C, 5(1), 1-10.

APPENDIX 1: Acceptability Questionnaire

Participant ID: Trial Form 1A

You are going to ride a bike that is fitted with 3 rider assistance systems. In each case imagine riding with the below systems and what the experience will feel like. Please indicate how acceptable you will find each system by ticking the box that most accurately expresses your feelings on each line.

1. An **advisory ISA system** which will advise you of the current speed limit of the road on which you are travelling. If you ride above the speed limit you will see flashing warning lights, hear a number of auditory warnings and feel a vibration in the saddle. This system does NOT restrict your speed.

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

2. An **assisting ISA system** which, in addition to the visual and physical warnings of the advisory system, will assist you in obeying the speed limit of the road.

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

3. An **information system** which will advise you of the layout of the road ahead (e.g. traffic lights, junctions).

useful						useless
pleasant						unpleasant
bad						good
nice						annoying
effective						superfluous
irritating						likeable
assisting						worthless
undesirable						desirable
raising alertness						sleep-inducing

PLEASE COMPLETE YOUR FIRST RIDE WITH ADVISORY ISA

ISA PTW Pre-System Acceptability Questionnaire (Advisory) Page 1 of 1