isa - UK
intelligent speed adaptation

Results of Field Trial 1

July 2005

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Project Funded by the
Transport Technology and Standards Division
Department for Transport

EXECUTIVE SUMMARY

Introduction

This report documents the first of a series of four field trials with Intelligent Speed Adaptation, i.e. a system in which the vehicle "knows" the speed limit and that knowledge can be used to constrain the maximum speed at which a vehicle can travel. The main focus of the trials is on driver behaviour when using ISA over a relatively long period, i.e. four months of driving. The ISA driving is compared with a pre period and an after period of driving without ISA. Both the pre and after periods are one month in duration, giving a total trial duration of six months. The experimental design allows comparison of driving without ISA in the pre period with driving with ISA active in the "system" period. It also allows comparison of the system period with the after period in order to reveal whether there any carry-over effects of the ISA driving on subsequent behaviour. The results presented here should not way be construed as predicting the results of the other field trials

For the purposes of this trial, 20 private motorists who do most of their driving in the Leeds area were recruited. Each of them was given the use of a modified vehicle for the trial period. These vehicles behave like "normal" cars apart from the ISA feature. Data was logged automatically on a hard drive that cannot be accessed by the user, and summary data was collected after each trip through a GSM (mobile phone) link. The ISA was overridable by the drivers, by mean of a button on the steering wheel or a kick-down on the throttle pedal. The speed limit map covered the Leeds area and the national trunk road network. The intention was to give drivers ISA support for almost all their regular driving during the ISA-active phase.

Method

Vehicles

The final selection for the ISA Phase 1 development, and subsequent fleet installation was made of the Skoda Fabia Elegance 1.4 litre estate. This vehicle being judged overall as the most appropriate package to address the declared needs of the ISA trial. The vehicle model is illustrated in Figure 1.

Figure 1: ISA fleet vehicle

Two computers were installed, the first to provide the information function (i.e. vehicle position and current speed limit), and the second to provide control (speed limiting) and data recording.

The overall concept was to integrate ISA system components and functionality into each vehicle so that the user would feel that the system had been installed as original equipment. In terms of user interface, the vehicles appeared much like "normal" cars. The main visible elements were:

- An additional LCD which was mounted centrally within the instrument cluster. This displayed ISA system status and speed limit information. It is easily seen through the steering column and has character sizing, contrast and format to the other OEM supplied LCD displays in the cluster.
- Two illuminated steering wheel mounted ISA reject (red) and ISA resume (green) buttons.

Figure 2 shows the steering wheel and instrument cluster. There was also an Emergency Disable button within the dashboard for use in the unlikely event of ISA system failure.

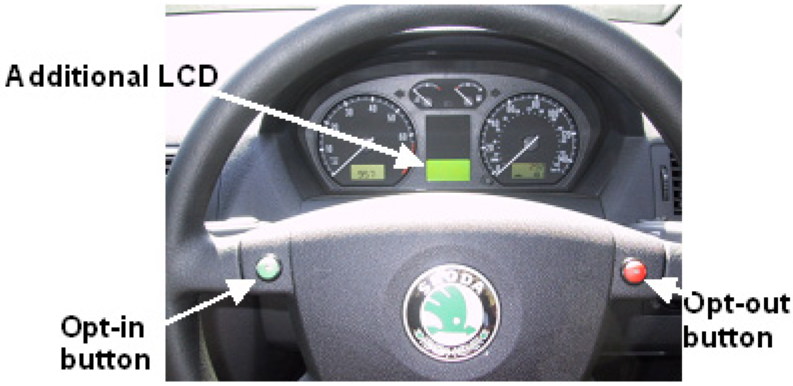

Figure 2: Steering-wheel-mounted buttons and ISA screen

Figure 3: ISA brake actuator

During the ISA active period, the system defaulted to being on and speed limit support was provided on all roads for which speed limit information was available. The LCD display indicated the speed limit. Elsewhere, the display would show "??" as the speed limit to indicate that the information was not available. Changes in speed limit were reinforced with an auditory beep. Driver demand for more throttle than required to keep within the speed limit was cancelled by the ISA system. Pushing the throttle pedal to a position substantially more than needed when cruising at or around the speed limit was discouraged through a vibration on the pedal. Mild check braking was also provided at a point roughly 10% over the speed limit. This would prevent the car speeding up too much on downhill gradients and would also slow the car if necessary on entry to lower speed zones. This braking was provided by an external actuator on the brake pedal as shown in Figure 3.

Mapped roads

Leeds Metropolitan District covers an area of approximately 400 km^2 and has 3042 km of road. Speed limits on these roads ranged from 20 mph to 70 mph. The digitised speed limit map was created with the cooperation of Leeds City Council. Figure 4 shows the distribution of speed zones on the digital speed map, which indicates that the majority of the roads in the Leeds trial area were 30 mph. The trunk road length covered in the speed limit database was 15,163 km, mostly with speed limits of 60 or 70 mph.

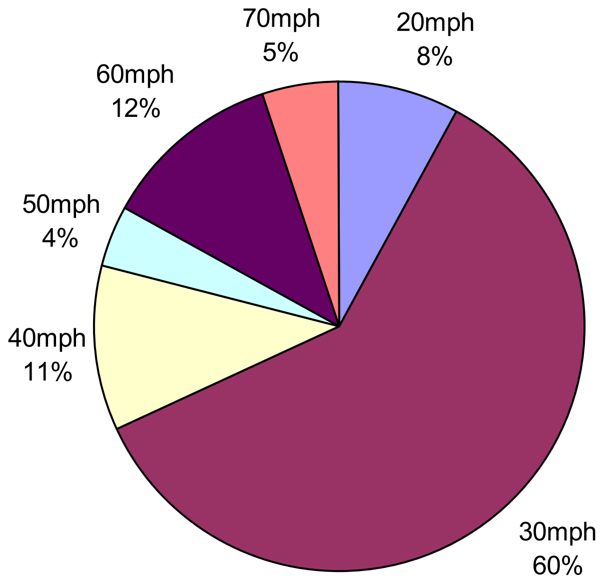

Figure 4: Distribution of speed zones in Leeds Metropolitan District

Trial participants

Ten males (age range 23–59 years) and ten females (age range 30–60 years) took part in the trial. Participants were recruited from a response to an advertisement placed in the Yorkshire Evening Post. The selected participants tended to:

- Have an average annual mileage exceeding 10,000 miles
- Undertake at least 80% of their driving within the area of Leeds Metropolitan District
- Demonstrate average mileage proportions by weekday/weekend split
- Demonstrate average exposure rates to different road types

The characteristics of the participants are shown in Table 1.

Table 1: Characteristics of Trial 1 participants

Gender	*Age*	*Attitudes to ISA*[1]	*Number*
Male	21–39	Negative	2
Male	21–39	Neutral	2
Male	21–39	Positive	1
Male	40–60	Negative	1
Male	40–60	Neutral	1
Male	40–60	Positive	3
Female	21–39	Negative	4
Female	21–39	Positive	1
Female	40–60	Negative	1
Female	40–60	Positive	4

[1]This refers to the results on attitudes towards ISA obtained from the initial attitudinal questionnaires

Major Results

Attitudinal changes

Data was generally gathered in the pre-ISA phase (Phase 1), during ISA operation (Phase 2) and after ISA was switched off (Phase 3). Usage of Intelligent Speed Adaptation had generally positive effects in terms of attitudes. Intention to speed was generally negative, meaning that respondents generally did not intend to speed. Intention to speed on urban roads was reduced after the ISA was switched on, and the reduction persisted into Phase 3 when the ISA was once again disabled (see Figure 5). Attitudes to speeding on urban roads became slightly more negative with ISA and this effect also persisted after the ISA was disabled. Attitudes to speeding on residential roads were even more negative, but were hardly affected by ISA and became slightly less negative when ISA was switched off. For urban and residential roads, but not for motorways, the system appears to have heightened drivers' awareness of the legal implications of speeding.

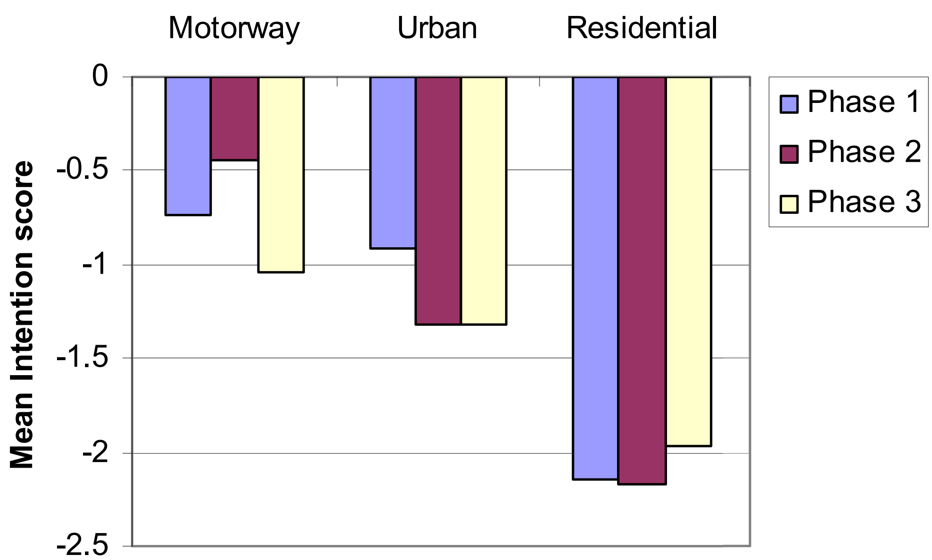

Figure 5: Intention to speed

Rather unexpectedly, there was generally an increase in drivers' perceived behavioural control. This is slightly surprising, because it was anticipated that driving with the system would decrease drivers' perceptions of control, since the system was taking control over some aspects of speed choice.

Drivers' self-reported propensity to exceed the speed in the previous month, shown in Figure 6, decreased during Phase 2 (except for the motorway scenario where there was a slight increase). For the urban and residential scenarios, self-reported speeding in Phase 3 increased but was still lower than that reported at Phase 1, suggesting that the effects of ISA may have been sustained even with unsupported driving. For the motorway scenario, self-reported speeding remained the same.

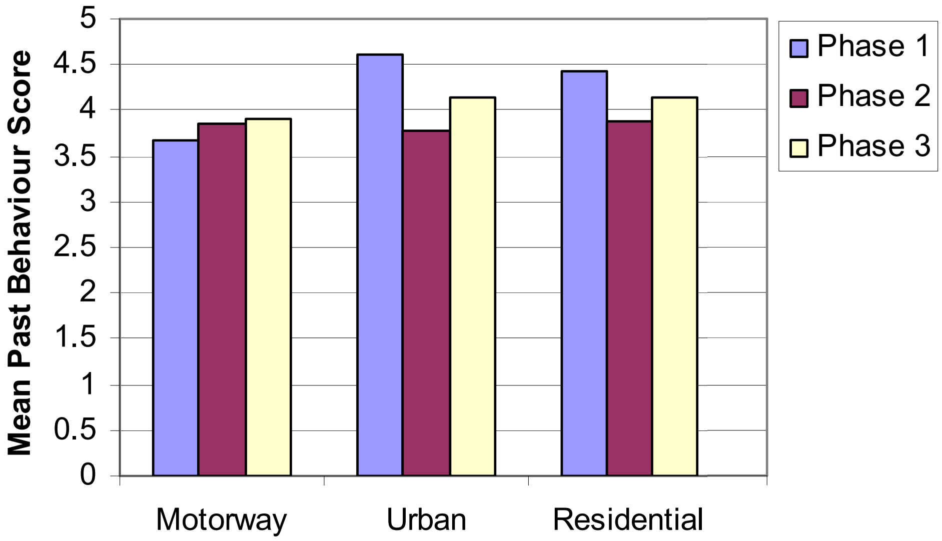

Figure 6: Self-reported speeding

Self-reported driving errors and violations both decreased with ISA and this effect persisted after the ISA was switched off. Acceptability of ISA was ascertained at four time points: in the pre-ISA phase, early in the ISA-enabled phase, late in the ISA-enabled phase, and after ISA was disabled (see Figure 7). The acceptability rating of the ISA system in terms of usefulness and satisfaction both improved over time. Usefulness may represent a social utility construct, whereas satisfaction has more to with fulfilment of personal goals. In the EVSC project, users' satisfaction ratings tended to go down once they used the ISA-equipped car. But in this trial satisfaction steadily improved over time, going from slightly negative to quite positive. It is quite encouraging that satisfaction was as its highest level after the system had been withdrawn.

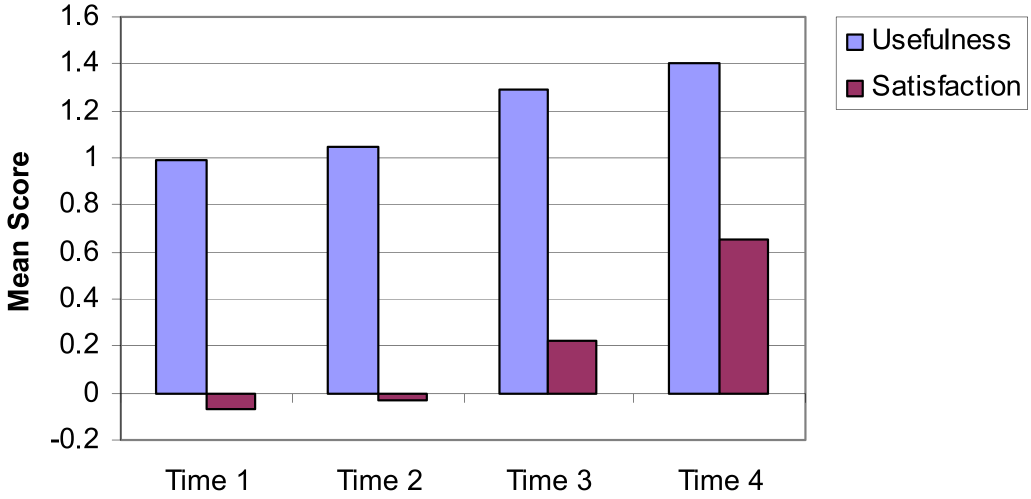

Figure 7: Acceptability of ISA

Behavioural changes

The ISA system was observed to have a distinctive effect in terms of the transformation of the speed distribution across all speed zones except the 60 mph zones. This means that speeds over the speed limit and in particular very high exceeding of the limit was curtailed. On the 60 mph roads, speeding behaviour was already rare in the pre period (the first month), so it is not surprising that there was little change with ISA. The lack of speeding in these roads is presumably due to traffic and road geometry conditions, and is in line with national data. On the other roads, when ISA was switched on, a large proportion of the speed distribution initially spread over the speed limit was shifted to around or below the speed limit. This is illustrated in Figure 8 which shows the percentage of distance travelled on 30 mph roads which occurred in various parts of the speed distribution. It should be noted that the ISA system used in the trial did not cut off speed sharply at 30 mph; hence the increase in travel at speeds between 30 and 35 mph when ISA was enabled.

Analysis of various statistics related to speed (mean, 85th percentile, etc.) revealed a ‘V’ shape across trial phases, i.e. the statistic goes down from Phase 1 to Phase 2, then up from Phase 2 to Phase 3. This pattern is especially prominent with respect to high percentiles of the speed distribution, which are strong indicators of speeding behaviour. ISA has not only diminished excessive speeding, but also led to a reduction in speed variation with positive implications for a reduction in accident occurrence.

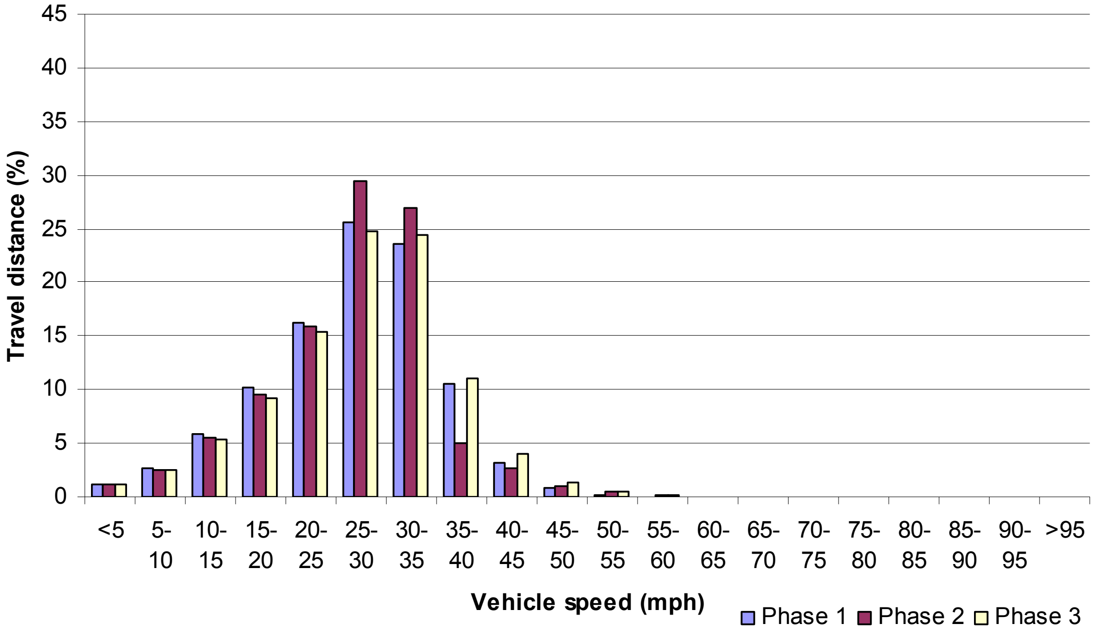

Figure 8: Speed distribution by phase on 30 mph roads

The use of an overridable ISA system also provides an opportunity to demonstrate potential resistance from the driving population against its implementation, based on true behaviour instead of opinion. ISA was overridden more often on urban roads with 20 and 30 mph zones where drivers are most likely to encounter conflicts with vulnerable road users such as pedestrians and cyclists than in the rest of speed zones (see Figure 9). It should be noted, however, that driving on 20 mph roads only accounted for 1% of total distance travelled in phase 2. In terms of demographic groups, male drivers, young drivers, and drivers who intend to break speed limits overrode the system more often than their counterpart drivers. Thus there is some tendency for ISA to be overridden on roads where it is perhaps needed most and by those drivers who in safety terms stand to benefit most from using it. As with other safety systems (e.g. seatbelts), there is therefore a tendency for those who need it most to use it least. This suggests that there may be a role for incentives to keep ISA active and discouragement of overriding when ISA is deployed on a voluntary or fleet basis.

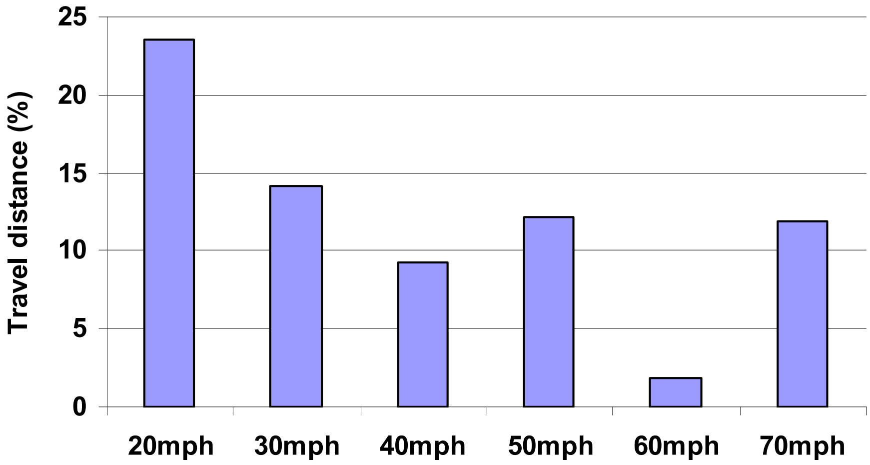

Figure 9: Proportion of distance travelled with ISA when the system was overridden

In spite these findings, ISA still had a positive impact on all groups, including young drivers, males and intenders to speed. In addition to improved speed limit compliance, ISA also contributes to diminished negative driving behaviour across demographic groups, as revealed by the observation drives. Presumably due to the constraint on breaking speed limits, travel time increased, which has led to a negative side effect of increased amber light violations. In addition, the results of the cluster trial shows that increased ISA penetration may facilitate vehicle headway stabilisation, which if realised generally should deliver positive benefits in terms of smoother operation and reduced accidents across the entire traffic network.

This trial has also revealed that participants seemed to have adapted their reference to chosen speed between trial phases. During Phase 1 and 3 when the ISA system was turned off, participants were observed to obey the speed limits with reference to speedometer reading. During Phase 2, participants were observed to rely on the ISA system (i.e. throttle cut-off) instead of the speedometer reading. This has implications because the design used here had the speedometer reading high but the ISA system using true speed, meaning that if drivers used the ISA system to regulate maximum speed that speed would be higher than when using the speedometer for the same purpose. The obvious solution is for the speedometer regulations to be changed so that they read accurately. In addition, the current design of the ISA system does not restrict vehicle speed to posted speed limits (i.e. the speed limits provided by the digital maps) to absolute precision. The throttle control permits vehicle speed to go somewhat over the speed limit, due to hysteresis in the ISA system response to driver throttle demand. If drivers relied on the system to keep them within the speed limit, they might actually be above the limit. This would need to be considered in setting standards for real-world ISA.

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1. INTRODUCTION

The ISA-UK project has as its major objective to investigate user behaviour with Intelligent Speed Adaptation (ISA) by means of set of field trials. For this purpose, twenty identical vehicles have been converted and provided with the capability to provide a voluntary (overridable) ISA system and to record data on each drive. Four successive trials are planned, each of six months duration. The four field trials are:

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 is in a major urban area, although the speed limit data cover the whole of the Leeds Metropolitan District, which includes some outlying rural areas and villages. The selected Leicestershire area is mainly rural and small-town. This report covers the results of the first trial.

The trials are designed to be non-intrusive — the vehicles behave like "normal" cars apart from the ISA feature, data is logged automatically, and summary data is collected after each trip through a GSM link. The ISA is overridable by the drivers. The intention is to give drivers ISA support for almost all their regular driving.

The main focus of the trials is on driver behaviour when using ISA over a relatively long period, i.e. four months of driving. The ISA driving is compared with a pre period and an after period of driving without ISA. Both the pre and after periods are one month in duration. The use of an experimental design in which driving after ISA has been switched off is included allows the examination of any carry-over effects of the ISA driving.

This report is structured into nine chapters. The following chapter specifies the infrastructure of the ISA system. The design of the field trial is detailed in the third chapter, followed by analysis results of questionnaire data, vehicle data, the observation drives, and the cluster trial. The eighth chapter summaries the findings and implications of the analysis results. Finally, the ninth chapter describes future analyses.

2. THE ISA SYSTEM

2.1 ISA system description

2.1.1 Requirements

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

These documents were:

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

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

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

2.1.2 Selection of host vehicle

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

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

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

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

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

1. Need to present a relatively “new” car to the participants who will be driving during the later part of the trials (i.e. up to and including 2005)
2. ABS, airbags, additional safety features, etc offers the participants the best vehicle for this trial

3. Use the most up to date technology
4. Respectable brand/Enhanced image from the start
5. Impression of refinement with a quiet engine and smooth ride

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

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

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

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

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

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

2.1.2.1 Final host vehicle evaluation

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

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

Figure 1: ISA fleet vehicle

2.1.3 Addition of the ISA hardware

2.1.3.1 Human Machine Interface

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

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

The following items were implemented:

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

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

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

2.1.3.2 Additional equipment for the ISA system

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

The standard radio aerial has been replaced with a combined GPS/GSM and radio antenna. An additional LCD is mounted centrally within the instrument cluster and can display a wide range of ISA system status and Speed Limit information. It is easily seen through the steering column and has character sizing, contrast and format to the other OEM supplied LCD displays in the cluster. The only other visible elements of the ISA system accessible to the driver are the two illuminated steering wheel mounted ISA accept and reject buttons (one green and one red) and an extra button set within the dashboard (see Figure 2 and Figure 3). It should be noted that these controls are colour coded and in the case of the override control utilise OEM switchgear of a comparable style and finish.

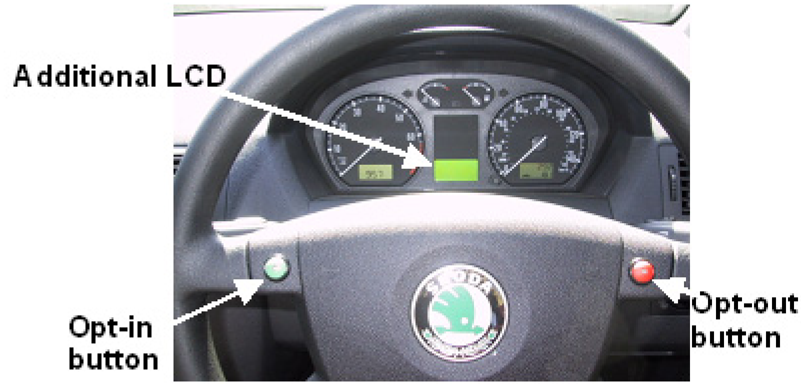


Figure 2: Steering-wheel-mounted buttons and ISA screen

An analogue I/O interface board is fitted to the rear of the glove box and an electrically driven pneumatic pump is housed in the engine bay (Figure 4) to power an actuator fitted to the brake pedal (Figure 5).

Figure 3: ISA override button

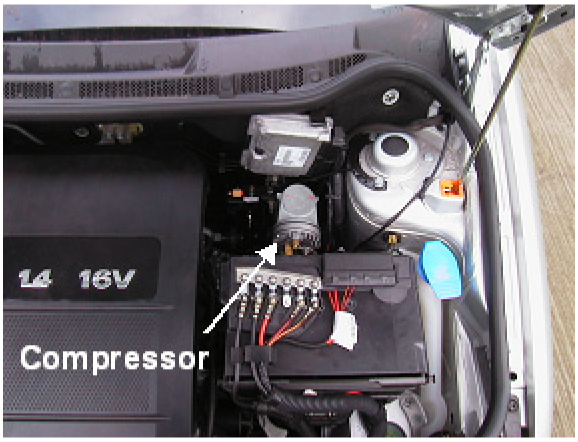


Figure 4: Under bonnet mounting of air compressor

Figure 5: ISA brake actuator

Two embedded computers, a proprietary sensor box that houses a GPS receiver, a yaw sensor, a speed pickup and direction of travel signal, together with the associated power supplies are all housed in a unit installed in the well next to the spare wheel (see Figure 6).

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

Figure 6: The main ISA equipment installed under the luggage storage area

2.1.4 General ISA architecture

The overall architecture of the ISA system is illustrated schematically in Figure 7.

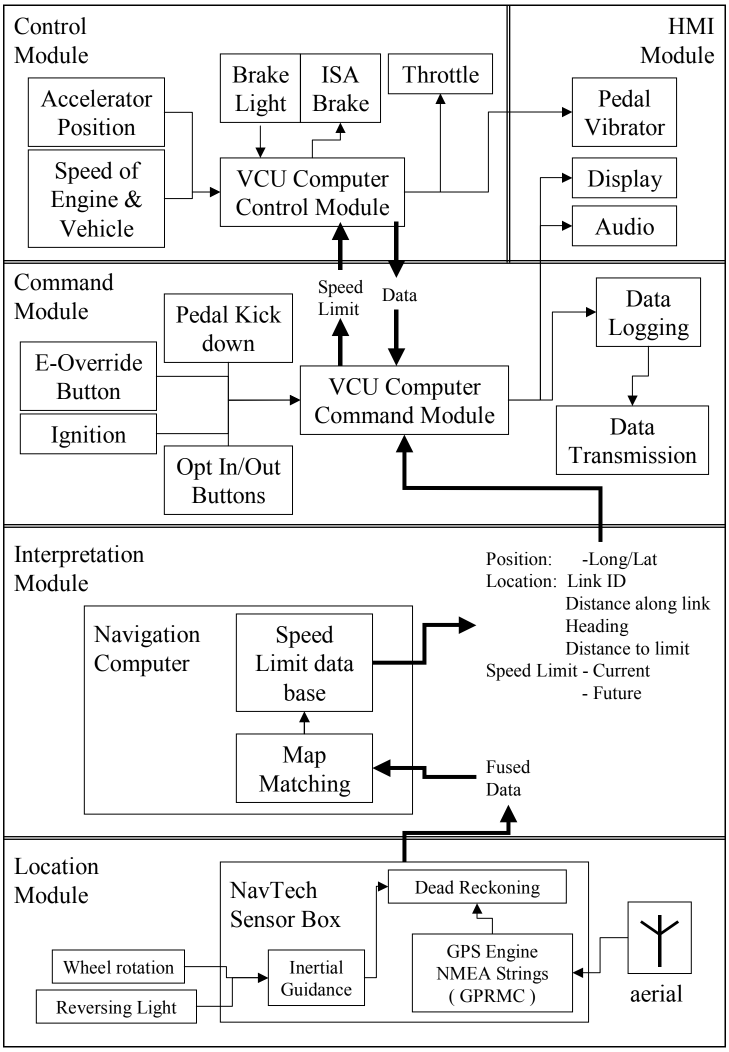


Figure 7: ISA system implemented on the ISA fleet cars

The system undertakes speed control and data acquisition tasks through four modules:

- Location
- Interpretation
- Command
- Control

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

2.1.5 Calibration of the ISA system

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

2.2 Operational states of the ISA system

When the vehicle speed is much less than the current speed limit, the driver's throttle demand is passed straight through to the engine ECU. When the vehicle speed is within 10% of the current speed limit the ISA system calculates the throttle demand to maintain the vehicle speed at the speed limit, compares this demand with the demand from the driver and passes the smaller value to the engine ECU. The following descriptions illustrate the various states of the ISA system as displayed to the driver following start-up of the vehicle.

2.2.1 ISA waiting

At the start of a journey the ISA waiting display may be seen as shown in Figure 8. This indicates that the ISA system is waiting for a message from the navigation system.

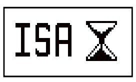


Figure 8: ISA Display, ISA Waiting

2.2.2 *ISA on, no speed limit*

When the ISA system is unable to establish a speed limit for the current link the display will show two question marks (see Figure 9).

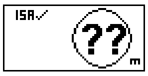


Figure 9: ISA Display, no speed limit

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

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

2.2.3 *ISA on*

The display shown to the driver when the ISA system is active and the speed limit is 30mph is shown in Figure 10. In order to limit the vehicle to the desired speed limit the ISA system intercepts the signal sent from the electronic throttle pedal to the Engine Control Unit (ECU). The ISA system can review this signal and determine the value that is required to limit vehicle speed to the maximum speed limit set for the road. The ISA system compares the current road speed with the speed limit. If the road speed exceeds the speed limit then the throttle signal to the engine control unit is reduced. If the road speed exceeds the speed limit by more than 2% then the ISA brake is applied until the road speed falls to the speed limit.

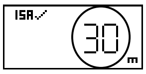


Figure 10: ISA Display, ISA on, 30mph speed limit

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

2.2.4 *Opt-out*

If the driver wishes to exceed the current speed limit, perhaps to pass a slow moving vehicle quickly, he can opt-out of ISA control by either pressing the red button on the steering wheel or by depressing the throttle pedal fully to reach the "kick-through" position. When the opt-out signal is received the ISA system responds by generating a sound, removing the circle from around the displayed speed limit (see Figure 11) and passing the driver throttle demand directly to the ECU.

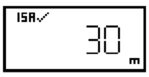


Figure 11: ISA display, Opt-Out, 30mph speed limit

ISA control can be restored in two ways:

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

2.2.5 Speed limit change

When the vehicle passes from one speed limit to another the driver is informed visually through the ISA display and by the new speed limit sound. The change in ISA display moving from a 30mph limit to a 40mph limit is shown in Figure 12.

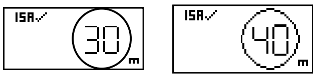


Figure 12: ISA display, moving from a 30mph limit to 40mph limit

2.2.6 ISA system fault

If certain fault conditions are identified during a trip then ISA control is suspended. The driver is informed visually through the ISA display (see Figure 13) and by the ISA Fault sound.

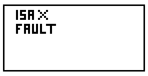


Figure 13: ISA display, Fault

The fault can only be cleared and ISA control returned by terminating the current journey and starting another through key-off and key-on.

2.2.7 Emergency Disable

The ISA Emergency Disable button (Figure 3), a modified Skoda switch, is clearly located directly above the vehicle radio/cassette on the control console, next to the ASR and below the hazard light buttons. It is for disabling the ISA system in the unlikely event of system failure. This was designed to be used in an ISA failure situation and was not to be used to opt-out of ISA control in normal driving.

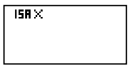


Figure 14: ISA display with system disabled

If the override button is pressed then all normal controls return and there is no speed control. The ISA display is shown in Figure 14. It should be noted that logging of the various locations, speed limits and vehicle speeds continues. The override button is reset at key-off.

3. FIELD TRIAL METHODOLOGY

3.1 Trial design

The field trial adopted an 'A-B-A' (i.e. ISA on, ISA off, ISA on) design with three distinct phases over 6-month trial duration, as illustrated in Figure 15.

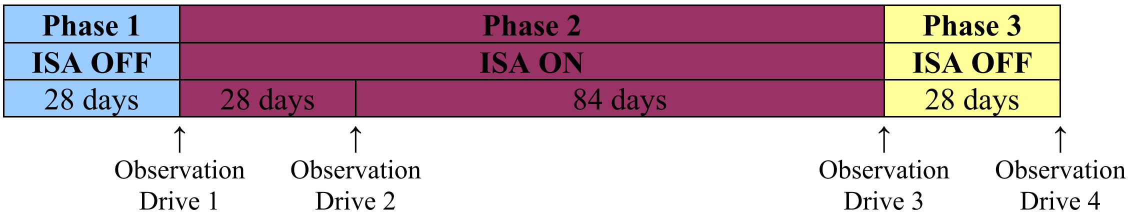


Figure 15: Field trial phases

Each participant was assigned to a vehicle and asked to undertake their normal travel behaviour for four weeks (i.e. Phase 1). This period allows the measurement of baseline driving behaviour, and therefore any changes in behaviour in the presence of ISA can be evaluated. At the end of the phase, participants attended an observation drive accompanied by two members of the research team. Upon finishing the observation drive, the ISA system was switched on, and participants subsequently started driving with ISA activated on a full-time basis (i.e. Phase 2).

When participants had driven the car with ISA activated for four weeks, they attended the second observation drive, and then carried on another 12-week driving period with ISA activated. This extended period of ISA driving over sixteen weeks provided the participants with the opportunity of experiencing all kinds of traffic scenarios and environments, and minimised the occurrence of novelty effects in the data collected.

At the end of Phase 2, participants attended the third observation drive. Upon finishing the observation drive, the ISA system was switched off. Participants subsequently started driving for another four weeks (i.e. Phase 3). When participants had completed Phase 3, they also attended the fourth observation drive. This phase of the trial was designed to assess any carry-over effects that ISA may have imposed on participants' driving style.

In addition, a cluster trial was carried out during Phase 2, in which participants were gathered together and drove on a predefined route six times. The purpose of the cluster trial was to simulate a high penetration of the ISA system in the traffic flow, in order to explore whether participant felt more comfortable on the ISA system when they were no longer the minority in the traffic flow, and to investigate any potential impact of the ISA system on the entire road network.

3.2 Participant recruitment

Ten males (age range 23-59 years, M = 39.90, SD = 11.96) and ten females (age range 30-60 years, M = 41.20, SD = 9.30) took part in the trial. Participants were recruited from a response to an advertisement placed in the Yorkshire Evening Post. All participants were recruited from the Leeds Metropolitan District area shown in Figure 16

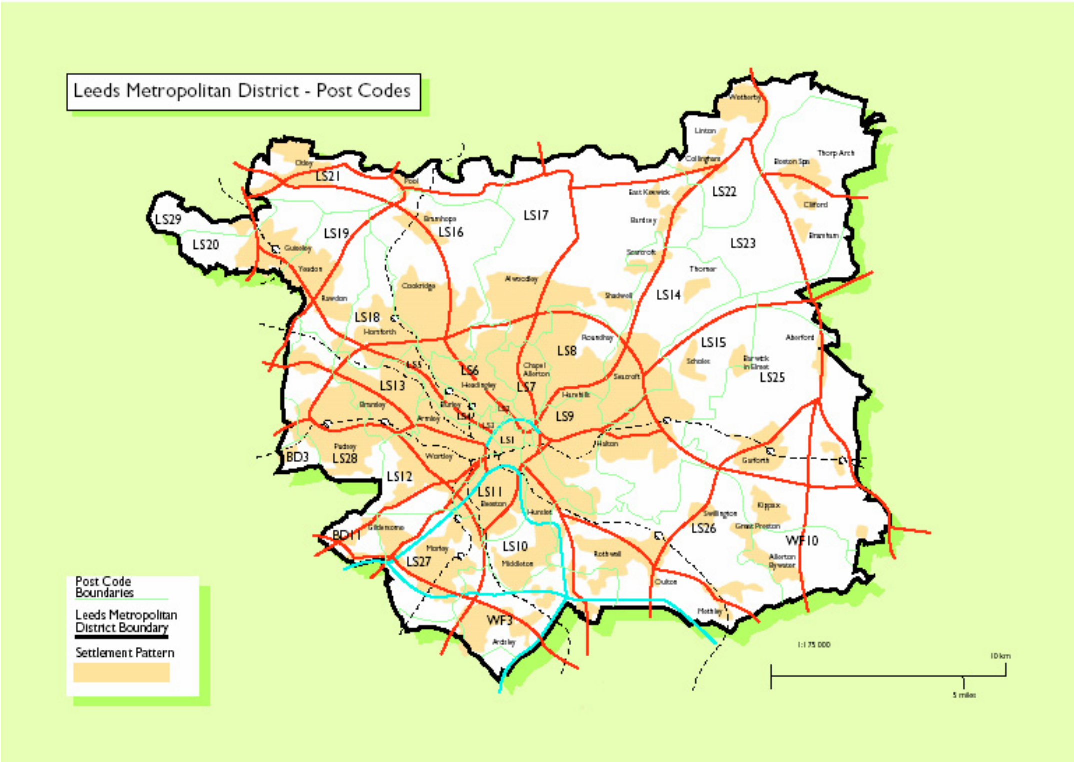


Figure 16: Leeds Metropolitan District

3.2.1 Selection criteria

Several criteria were used when selecting the participants:

3.2.1.1 Current vehicle status

Respondents were asked to describe the vehicles that they have access to in terms of vehicle make, model and its age. This information was used to ensure that those respondents who are participating in order to "drive a new car for a while" were discarded. Respondents were also asked to state the proportion of their driving spent in this car in order to exclude multi-vehicle users (as this would introduce noise into the data).

3.2.1.2 Exposure

The success of the data collection procedure depended, in part, on the amount of driving undertaken within the specified digital map area. Therefore selection was also based upon:

- Average annual mileage
- Monthly mileage within [specified map] area
- Typical weekly exposure (weekday/weekend)
- Exposure on different road types (urban/rural/motorway)

Selected participants tended to:

- Have an average annual mileage exceeding 10,000 miles
- Undertake at least 80% of their driving within the specified map area
- Demonstrate average mileage proportions by weekday/weekend split (based on NTS data)
- Demonstrate average exposure rates to different road types (based on NTS data)

3.2.1.3 Accidents and driving convictions

A full driving history was obtained from the respondents, including details of any driving convictions they had. Respondents who had been convicted of driving under the influence of alcohol or other illicit substances and those who have been involved in more than two accidents in the previous three years were discarded. By eliminating these high-risk drivers, it was hoped that the likelihood of serious incidents would be minimal.

3.2.1.4 Attitudes

A common problem with safety studies is that samples can be skewed with regards to the types of people that volunteer for them. It was the aim of the project to include participants with a wide range of "pre" attitudes to ISA and other forms of speed management. Whilst it was important to exclude intentional violators or those with driving convictions, it was also essential to include representatives of the general driving population who exceed the speed limit.

In order to achieve these prerequisites, respondents were asked to complete a questionnaire that identified their general attitudes to disengaging ISA using the Theory of Planned Behaviour. Attitudes were assessed by eight semantic differential scales following the statement 'Disengaging the ISA system would be…' (useless-useful, harmful-beneficial, negative-positive, bad-good, unsafe-safe, unsatisfying-satisfying, not enjoyable-enjoyable, reckless-cautious; scored −3 to +3). Participants were selected to reflect positive (scores above 0), neutral (scores equal to 0) and negative attitudes (scores below 0).

3.2.1.5 Demographics

The sample was also balanced for gender and age. It was intended to polarise participants into two age groups (25-40; 41-60).

3.2.2 Final selection

The participant selection process outlined in the initial tender intended to recruit a group of participants reflecting the characteristics noted in Table 1.

Table 1: Intended characteristics of Trial 1 sample

Participant	*Gender*	*Age*	*Exposure*	*History*	*Attitudes*[1]
1	Male	25–40	All drivers will have reported average annual mileages of >10,000 miles. In addition, all will have a high proportion of their driving in the specified map area.	No history of driving convictions and no more that 2 (at-fault) accidents in 3 years.	Negative
2	Male	25–40			Negative
3	Male	25–40			Neutral
4	Male	25–40			Positive
5	Male	25–40			Positive
6	Male	41–60			Negative
7	Male	41–60			Negative
8	Male	41–60			Neutral
9	Male	41–60			Positive
10	Male	41–60			Positive
11	Female	25–40			Negative
12	Female	25–40			Negative
13	Female	25–40			Neutral
14	Female	25–40			Positive
15	Female	25–40			Positive
16	Female	41–60			Negative
17	Female	41–60			Negative
18	Female	41–60			Neutral
19	Female	41–60			Positive
20	Female	41–60			Positive

During the course of the trial however, two participants withdrew from the study before they received their ISA car as they had bought a brand new car and been given a company car. One participant was also withdrawn from the study as he made little use of the ISA car and after becoming unemployed ceased to use the car. During recruitment it proved difficult to find replacement participants that matched on all of the selection criteria. In response to these difficulties the age ranges of the participants were changed to 21-39 yrs and 40-60 yrs. This allowed to us to shift current participants into categories where the number of potential recruits was low and thus recruit from categories with a high potential participant sample. The final sample achieved is shown in Table 2.

[1] Attitudes refer to the results obtained from the attitudinal questionnaires.

Table 2: Actual characteristics of Trial 1 sample

Participant	*Gender*	*Age*	*Exposure*	*History*	*Attitudes*[2]
1	Male	21–39	All drivers will have reported average annual mileages of >10,000 miles. In addition, all will have a high proportion of their driving in the specified map area.	No history of driving convictions and no more that 2 (at-fault) accidents in 3 years.	Negative
2	Male	21–39			Negative
3	Male	21–39			Neutral
4	Male	21–39			Neutral
5	Male	21–39			Positive
6	Male	40–60			Negative
7	Male	40–60			Neutral
8	Male	40–60			Positive
9	Male	40–60			Positive
10	Male	40–60			Positive
11	Female	21–39			Negative
12	Female	21–39			Negative
13	Female	21–39			Negative
14	Female	21–39			Negative
15	Female	21–39			Positive
16	Female	40–60			Negative
17	Female	40–60			Positive
18	Female	40–60			Positive
19	Female	40–60			Positive
20	Female	40–60			Positive

Although this does not split the participants on attitudes across the four groups it was the best attempt possible with the available sample that could achieve an even overall split across attitudes.

Respondents selected to take part in the trial were then required to sign an agreement (given in Appendix A) between the University of Leeds and themselves covering issues such as data collection, insurance claims and car maintenance procedures.

3.2.3 Demographic and driving characteristics

Several items sought information about key demographic and driving characteristics in order to give a brief overview of the sample.

Table 3: Age by attitude group

	N	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Negative	8	36.13	4.76	30	43
Neutral	3	35.00	12.00	23	47
Positive	9	46.33	11.60	28	60

As can be seen in Table 3, it was difficult to recruit participants at the extremes of the age group ranges with the majority aged within the 30-50 yr age bracket.

[2] Attitudes refer to the results obtained from the attitudinal questionnaires.

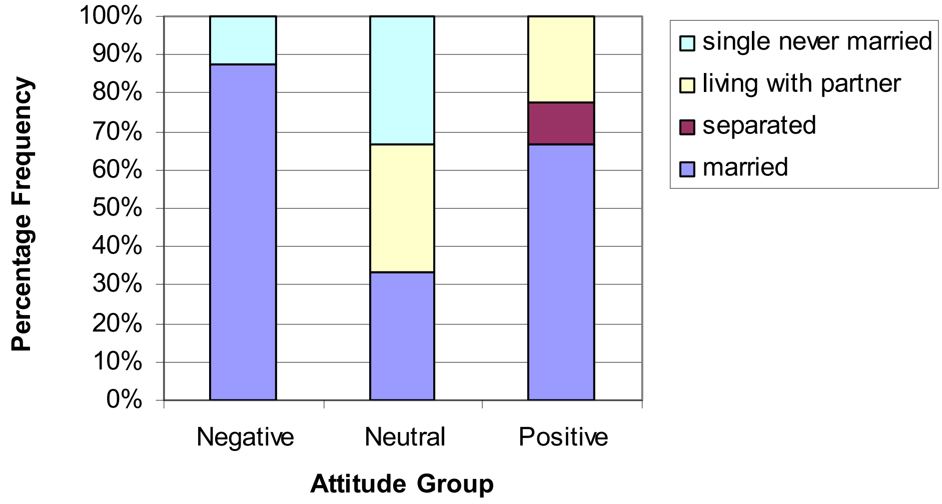


Figure 17: Marital status by attitude group

Figure 17 shows little variation across the groups in terms of their marital status with 85% of the participants married or living with a partner. Forty percent of the participants also had one or more children aged 18 or under living with them (see Figure 18).

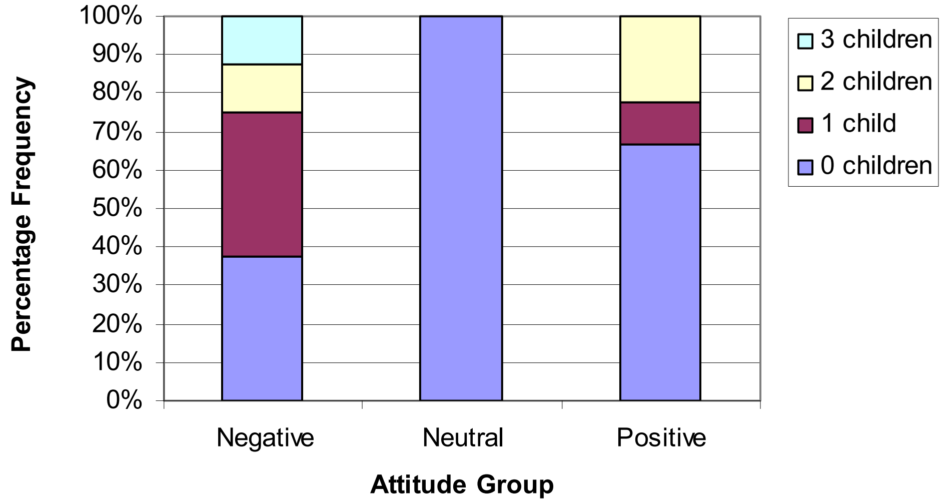


Figure 18: Number of children (18yrs and under) living at home by attitude group

When comparing participants' National Statistics Socio Economic classification there was again little variation across the groups. Negative and neutral participants tended to hold more managerial and professional occupations (see Figure 19).

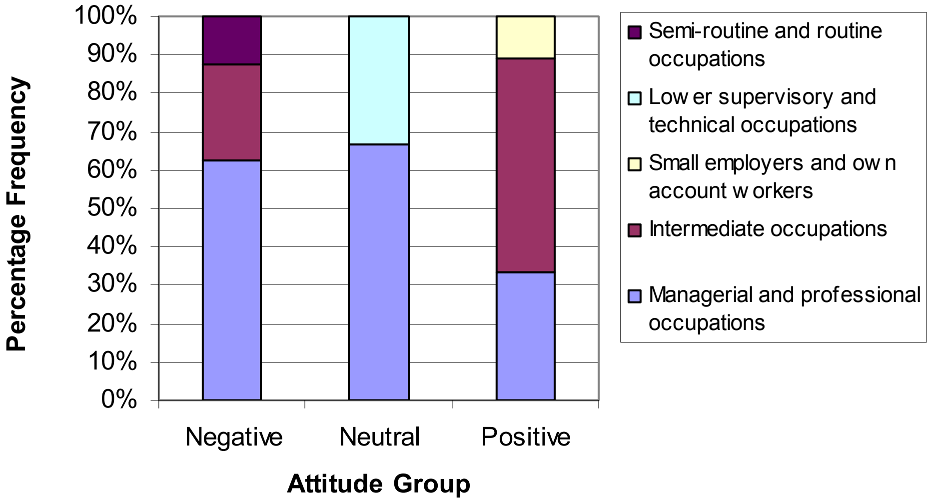


Figure 19: NS-SEC classification by attitude group

Table 4 provides an overview of the participants' self reported mileage and trip frequency. As required the participants generally accrued an average annual mileage that exceeded 10,000 miles and spent at least 80% of their time driving within the Leeds area. Comparison across the group suggests that participants holding a positive attitude towards ISA tended to be those who accrued the highest mileage and made the greatest number of trips per week.

Table 4: Participants mileage and trip statistics

	Negative	Neutral	Positive
Leeds weekday mileage	164.30	145.67	223.44
Leeds w/end mileage	74.66	53.00	73.78
Leeds total weekly mileage	238.96	198.67	297.22
Leeds monthly mileage	955.85	794.67	1188.89
Leeds annual mileage	12426.05	10330.67	15455.56
Total annual mileage	15804.75	13346.67	17668.44
% of driving in Leeds area	81.16	79.82	89.20
No. weekday trips	30.88	33.67	34.78
No. of w/end trips	9.88	9.67	9.44
Total weekly trips	40.75	43.33	44.22

Three participants had received three points for speeding within the last 5 years — one participant from each attitude group. Four of the participants (2 positive, 2 negative) had been involved in an accident in the last 5 years.

3.3 Data collection

A wide range of data was collected during the trial, including objective measures recorded by the vehicle, and subjective measures obtained through questionnaires. These are specified in the following sections, followed by a description of the data management system.

3.3.1 Objective measures

Although the focus of this project is travelling speed and speed limits, many other parameters were recorded during the course of a trip, such as time stamps and coordinates etc, at 10 Hz (i.e. 10 records per second) by the data logging system installed in the vehicle. The purpose of recording coordinates was to enable replication of a trip should it be required at a later date. Many trip based parameters, for example trip length, trip duration and fuel usage, were also recorded by the vehicle's logging system. A full specification of the vehicle data is given in Appendix B.

3.3.2 Subjective measures

3.3.2.1 General speeding and experience with system

Several items sought information regarding participants' attitudes towards the acceptability and frequency of speeding in several situations. Items also sought information regarding participants' experience of the system including perceptions of the risk and frustration associated with driving under ISA control on certain roads. These results shall be commented on in a later deliverable.

3.3.2.2 The Theory of Planned Behaviour

The TPB was applied to four risky driving behaviours. These behaviours were:

Speeding on a motorway: Imagine you are driving along a motorway. It is a fine, dry day and the traffic is fairly light. The speed limit of the road is 70mph.

Speeding on a residential road: Imagine you are driving along a residential road with cars parked either side or connecting side roads at various points. Pedestrians are also visible. The speed limit of the road is 30 mph.

Speeding on an urban road: Imagine you are driving along an urban road. The traffic is fairly light. Although there are houses either side of the road there does not appear to be many pedestrians. The speed limit of the road is 40 mph.

Disengaging an ISA system: Imagine you are driving a car that is fitted with Intelligent Speed Adaptation. When you start up the car you are automatically speed limited. You cannot drive above the posted speed limit unless you decide to press one of the override buttons and disengage the system. If you disengage the system you are free to travel at your desired speed.

Individual TPB measures

The questionnaires included direct and indirect measures of the TPB constructs.

Intention was assessed using three items. Items sought to measure *intentions* (one item; 'I would intend to exceed the 70mph speed limit on a motorway', strongly disagree-strongly agree, scored −3 to +3), *desire* (one item; 'I would want to exceed the 30mph speed limit on a residential road', strongly disagree-strongly agree, scored −3 to +3) and *planning* (one item; 'I would plan to exceed the 40mph speed limit on an urban road', strongly disagree-strongly agree, scored −3 to +3). Distinctions here were based on Conner and Sparks (1996) recommendations and higher scores reflect stronger intentions to perform the behaviour. Factor analysis confirmed that the three items loaded onto one dimension for each behaviour. The mean of these three items produced a composite scale for each of the four questionnaires.

Table 5: Reliability scores of intention measures

Scenario	Pre ISA	During ISA	Post ISA
Motorway 70 mph	0.86	0.95	0.95
Residential 30 mph	0.82	0.92	0.63
Urban 40 mph	0.61	0.95	0.93
Disengage ISA	0.46	0.86	0.79

Perceived behavioural control (PBC) was assessed using six items. These items were differentiated in terms of *perceived difficulty* (two items; e.g., 'For me to disengage the ISA system would be…', difficult-easy, scored +1 to +7), *perceived control* (three items; e.g., 'How much control would you have over exceeding the speed limit on a motorway?', no control-complete control, scored +1 to +7) and *self efficacy* (one item; 'How confident are you that you will be to exceed the 30mph speed limit on a residential road?', not very confident-very confident, scored +1 to +7), as proposed by Conner and Sparks (1996) and Trafimow, Sheeran, Conner and Finlay (2002). Factor analysis with varimax rotation revealed inconsistent loading onto the three factors (perceived difficulty, perceived control and self efficacy) across the four questionnaires. Therefore the three indexes for perceived behavioural were collapsed to form one scale. The mean of these six items produced a composite scale for each of the behaviours. Higher scores reflected greater perceptions of control in the commission of the behaviour.

Table 6: Reliability score for PBC measures

Scenario	Pre ISA	During ISA	Post ISA
Motorway 70 mph	0.68	0.82	0.89
Residential 30 mph	0.80	0.87	0.85
Urban 40 mph	0.76	0.80	0.90
Disengage ISA	0.73	0.96	0.85

Attitude was assessed by eight semantic differential scales following the statement 'Exceeding the 40mph speed limit on an urban road would be…' Following Lawton, Parker, Manstead and Stradling's (1997) distinction, the seven point scales measured both instrumental (useless-useful, harmful-beneficial, negative-positive, bad-good) and affective attitudes (unsafe-safe, unsatisfying-satisfying, not enjoyable-enjoyable, reckless-cautious). Factor analysis with varimax rotation revealed inconsistent loading onto two factors across the four questionnaires. The two separate indexes for instrumental and affective attitudes were collapsed to form one attitude scale for each behaviour. The mean of the eight items (all scored −3 to +3) produced a composite scale for each of the behaviours such that higher scores indicate attitudes that were in favour of the commission of the behaviour.

Table 7: Reliability scores for attitude measures

Scenario	Pre ISA	During ISA	Post ISA
Motorway 70 mph	0.90	0.93	0.94
Residential 30 mph	0.94	0.95	0.93
Urban 40 mph	0.94	0.94	0.97
Disengage ISA	0.91	0.95	0.90

Normative beliefs Four salient referents were identified; the police, family, other road users and other spouse/partner. Four items measured normative beliefs (e.g., 'The police would disapprove of me disengaging the ISA system', strongly disagree-strongly agree, scored −3 to +3). Higher scores reflected normative beliefs that supported or opposed the behaviour (see findings).

Motivations to comply were assessed using four items (e.g., 'Generally speaking how much do you want to do what your family think you should do?', not at all-very much, scored +1 to +7). Higher scores reflected a stronger motivation to comply with the referents.

Behavioural beliefs were measured using six items (e.g., 'Exceeding the 70mph speed limit on a motorway would risk causing an accident', unlikely-likely, scored −3 to +3). Higher scores reflected beliefs that the outcome was likely.

Outcome evaluations were assessed using six items (e.g., 'Making rapid progress would be…, bad to good, scored −3 to +3). Higher scores reflected outcome evaluations that were positive.

Control Beliefs were measured using seven items ('Driving at nighttimes makes my exceeding the 40mph speed limit', unlikely-likely, scored −3 to +3). Higher scores reflected beliefs that the outcome was likely. Three additional items were included for disengage scenario.

Frequency of beliefs was measured using seven items ('I drive on urban roads at nightime', never-frequently, scored +1 to +7). Higher scores reflected behaviours that were more frequent. Three additional items were included for disengage scenario.

Moral norm was assessed using a single seven-point item ('It would be quite wrong for me to exceed the 30mph on a residential road, strongly disagree-strongly agree, scored +1 to +7). Higher scores reflected stronger moral norms.

Anticipated regret was measured as the mean of two seven-point items (e.g., 'I would regret exceeding the 40mph speed limit on an urban road', unlikely-likely, scored −3 to +3). Higher scores reflected stronger feelings of anticipated regret.

Table 8: Reliability scores for anticipated regret measures

Scenario	Pre ISA	During ISA	Post ISA
Motorway 70 mph	0.89	0.88	0.98
Residential 30 mph	0.62	0.94	0.99
Urban 40 mph	0.85	0.96	0.90
Disengage ISA	0.78	0.99	0.88

Past behaviour was tapped by two seven point items (e.g., 'In the past I have frequently disengaged the ISA system', strongly disagree-strongly agree, and scored 1 to 7). Higher scores reflected more frequent commission of the behaviour in the past.

Table 9: Reliability scores for past behaviour measures

Scenario	Pre ISA	During ISA	Post ISA
Motorway 70 mph	0.96	0.94	0.85
Residential 30 mph	0.99	0.88	0.79
Urban 40 mph	0.88	0.88	0.91
Disengage ISA	-	0.53	-

Self-identity was measured using one single item (e.g., 'I see myself as a safe driver', strongly disagree-strongly agree, scored +1 to +7). Higher scores reflected a stronger sense of self-identity.

Risk perception was assessed using one item (e.g., What is the risk of being involved in a accident if you exceed the 70mph speed limit on a motorway', very low risk-very high risk, scored +1 to +7). Higher scores reflected higher perceptions of risk.

3.3.2.3 Acceptability

Driver acceptance of the ISA system under different penetration levels was measured using an acceptability scale of advanced transport telematics developed by Van de Laan, Heino and De Waard (1997). The simple scale provided a direct measure of attitudes towards systems. Nine items measured participant's views of ISA allowing system evaluation across the dimensions of usefulness and satisfaction. Administration of the questionnaire at four time points allowed the calculation of an end score for each participant on the two dimensions of "usefulness" (e.g., useful-useless, scored +2 to –2) and "satisfaction" (e.g., pleasant-unpleasant, scored +2 to –2). A practical system evaluation was gauged by the usefulness score, whilst satisfaction scores reflected the systems pleasantness. High scores reflected positive appraisals of the systems usefulness and high satisfaction with the system. In a comparison of six studies high scale reliability was found (Van de Laan, Heino and De Waard, 1997). De Waard, Van der Hurst and Brookhuis (1999) have since utilized the scale. Comte's (2000) inclusion of the acceptability scale in her investigation into the impact of Intelligent Speed Adaptation on driver behaviour alludes to its merit in the present study.

Table 10: Reliability scores for acceptability measures

Measure	Time 1	Time 2	Time 3	Time 4
Usefulness	0.85	0.75	0.72	0.81
Satisfaction	0.86	0.85	0.88	0.86

3.3.2.4 Driver Behaviour Questionnaire

Self reported driving violations and errors were assessed using the shortened 24-item version of the Driver Behaviour Questionnaire (Parker, Reason, Manstead and Stradling, 1995). This instrument measured the frequency with which individuals commit various types of errors and violations when driving, identifying three distinct types of aberrant driving behaviours; errors, lapses and violations. Participants were presented with 24 aberrant driving behaviours and asked to rate how often they have committed these (0 = never, 1 = hardly ever, 2 = occasionally, 3 = quite often, 4 = frequently, 5 = nearly all the time). In a comparison between the 50-item and 24-item scale good internal consistency has been found for each of the three subscales (Cronbach's α coefficients 0.84 for the errors, 0.8 for the violations, and 0.72 for lapses). The three factors first identified in Reason, Manstead, Stradling, Baxter and Campbell (1990) was confirmed. Testretest correlation's also demonstrated reliability over time (time1 and time 2 correlations were 0.69 for error scale, 0.81 for the violation scale and 0.75 for the lapse scale).

Eight items measured *errors* (e.g., 'Attempt to overtake someone that you hadn't noticed to be taking a right turn', never-nearly all the time; scored 0 to +5). High scores reflected a greater propensity to perform the behaviour.

Eight items measured *lapses* (e.g., 'Attempt to drive away from traffic lights in third gear', never-nearly all the time; scored 0 to +5). High scores reflected a greater propensity to perform the behaviour.

Eight items measured *violations* (e.g., 'Disregard the speed limits late at night or early in the morning', never-nearly all the time; scored 0 to +5). High scores reflected a greater propensity to perform the behaviour.

Table 11: Reliability scores for DBQ measures

Measure	Time 1	Time 2	Time 3	Time 4
Lapse	0.68	0.63	0.73	0.73
Error	0.77	0.73	0.55	0.85
Violation	0.80	0.71	0.72	0.69

3.3.2.5 Sensation seeking

The Arnett (1994) Sensation Seeking Scale was used. Although the Sensation Seeking Scale Form V (Zuckerman, 1994) is one of the most popular and widely used sensation seeking scales (especially in driver behaviour research, see Jonah, 1997) it was felt that the 40 forced choice items would overload the respondents given the lengthy nature of the TPB questionnaires. As Arnett points out, it is often hard for individuals to chose between these items when both or neither applies. Secondly, since many of the items relate to physical activity, it may be that any age differences in responses would indicate differences in physical strength and not sensation seeking. The Arnett sensation seeking scale provided a short 20 item questionnaire which asked respondents to rate how likely each described them. The scale is composed of two dimensions; novelty and intensity. The internal reliability of each was tested.

Novelty subscale 10 items measured novelty (e.g., 'I think it fun and exciting to perform or speak in front of a group', does not describe me at all-describes me very well, scored +1 to +4; Cronbach's $\alpha = 0.43$).

Intensity subscale 10 items assessed intensity (e.g., 'When I listen to music I like it to be loud', does not describe me at all-describes me very well scored +1 to +4; Cronbach's $\alpha = 0.62$)

Higher scores reflected a higher level of sensation seeking.

3.3.2.6 Driving Style Questionnaire

The DSQ (West, Elander and French, 1992) contains 15 items based on behaviours that are associated with risky driving behaviour. Participants were asked on what basis they engaged in these behaviours (never or very infrequently-very frequently or always; scored +1 to +5)

3.3.2.7 Conscientiousness

The facets of conscientiousness were measured using a questionnaires developed as part of the International Personality Item Pool. Five facets were taken to represent those in the NEO-PI-R (http://ipip.ori.org/newNEOKey.htm)

Self efficacy 10 items measured self efficacy (e.g., 'complete task successfully', very inaccurate-very accurate scored +1 to +5; Cronbach's α = 0.76).

Orderliness 10 items measured orderliness (e.g., 'like order', very inaccurate-very accurate scored +1 to +5; Cronbach's α = 0.84).

Dutifulness 10 items measured dutifulness (e.g., 'try to follow the rules, very inaccurate-very accurate scored +1 to +5; Cronbach's α = 0.76).

Achievement Striving 10 items measured achievement striving (e.g., 'demand quality' very inaccurate-very accurate scored +1 to +5; Cronbach's α = 0.56).

Self Discipline 10 items measured self discipline (e.g., 'get chores done right away', very inaccurate-very accurate scored +1 to +5; Cronbach's α = 0.78).

Cautiousness 10 items measured cautiousness (e.g., 'Avoid mistakes' very inaccurate-very accurate scored +1 to +5; Cronbach's α = 0.74).

Higher scores reflected a higher level of conscientiousness.

3.3.2.8 Questionnaire administration

Questionnaires were generally administered at four time points;

Time 1: one month prior to ISA control,
Time 2: following one month ISA control,
Time 3: following four months ISA control and
Time 4: following a one month return to non-ISA-controlled driving.

The majority of questionnaires were administered according to this timetable so that behavioural changes to ISA could be monitored. However as can be seen in Table 12 certain questionnaires were administered at a differing schedule. Personality measures such as the sensation seeking, conscientiousness and the driving style questionnaire were administered at Time 1 only since personality traits are assumed to remain constant over time. It was also felt too difficult to expect participants to make certain judgments regarding system safety and design without any experience of the system. At Time 4 questionnaires relating to ISA usage became irrelevant. The TPB was administered at 3 time points only.

Table 12: Administration schedule for questionnaires

Questionnaire	Phase 1	Phase 2		Phase 3
	Time 1	Time 2	Time 3	Time 4
Demographic/general driving	✓			
TPB	✓		✓	✓
NASA RTLX	✓	✓	✓	✓
Acceptability	✓	✓	✓	✓
DBQ	✓	✓	✓	✓
Sensation Seeking	✓			
Conscientiousness	✓			
General speeding	✓	✓	✓	✓
Concentration	✓	✓	✓	
Experience of system	✓	✓	✓	
System design and safety		✓	✓	
System trust		✓	✓	
Stakeholder	✓		✓	

3.3.3 Data management

3.3.3.1 In-vehicle data logging system

Data collected by the vehicle was stored in three separate files at the end of each trip. These are specified as follows:

The main data file is a continuous ASCII stream recording vehicle speed, speed limits, coordinates, and time stamps etc at 10 Hz.

The summary file contains trip based information such as time stamps and coordinates of the origin and destination, date, trip length, fuel usage, ISA usage etc.

The error log file records any system failures during the trip and is only used for fault investigations.

All of the above files are stored on the hard disk in the vehicle. Identical files are also duplicated on a second hard disk to reduce the potential impact of data loss due to failure of a hard disk. The available space on each disk is checked during each trip. When the capacity has fallen below 20% of the full capacity, a warning message is sent to the research team at Leeds University and MIRA.

3.3.3.2 SMS workstation

Although the summary file is recorded on the in-vehicle hard disks, it is also sent as an SMS message through mobile phone network at the end of each trip to a dedicated workstation at Leeds University. The workstation is equipped with a SMS receiver. After the SMS has reached the workstation, the content is converted and written into a Microsoft Access database via a Java application, Swiftnote. The software was developed by NCL Ltd, Ireland, and has been provided to the project free of charge on an academic licence.

3.3.3.3 Data server

The ISA data server is a Dell PowerEdge 2600 equipped with an Intel Xeon processor and 1GB memory which runs Microsoft SQL server 2000. The data files stored in the vehicles are downloaded to a laptop at the end of each trial phase, which are subsequently converted and written into the SQL database. All questionnaire data are also uploaded to the SQL database. The SQL database contains various tables hosting data from different sources and provides links to integrate data across the tables when data analysis is carried out. Figure 20 illustrates the structure of the ISA data server.

To prevent data loss due to accidental events, the content of the SQL server is backed up incrementally onto DVDs upon the addition of new data. At the end of each trial, the complete data set is also backed up onto DVDs separately.

3.3.3.4 Operational logs

A comprehensive logging system was established to enable efficient management of the ISA fleet and data collection activities. The research team at Leeds University keeps two log files. The first file is dedicated to recording all activities regarding data collection such as the date and time for vehicle handover, vehicle swapping (i.e. due to ISA system malfunction), and observation drives etc. This file is essential for identifying correct blocks of data from the SQL database with respect to individual participants and associated vehicles that they had driven. The second file is dedicated to recording vehicle faults, which builds up a system malfunction history for individual vehicles enabling the technical team at MIRA to develop appropriate remedies. The technical team at MIRA also keeps a log file of remedies applied to individual system malfunctions.

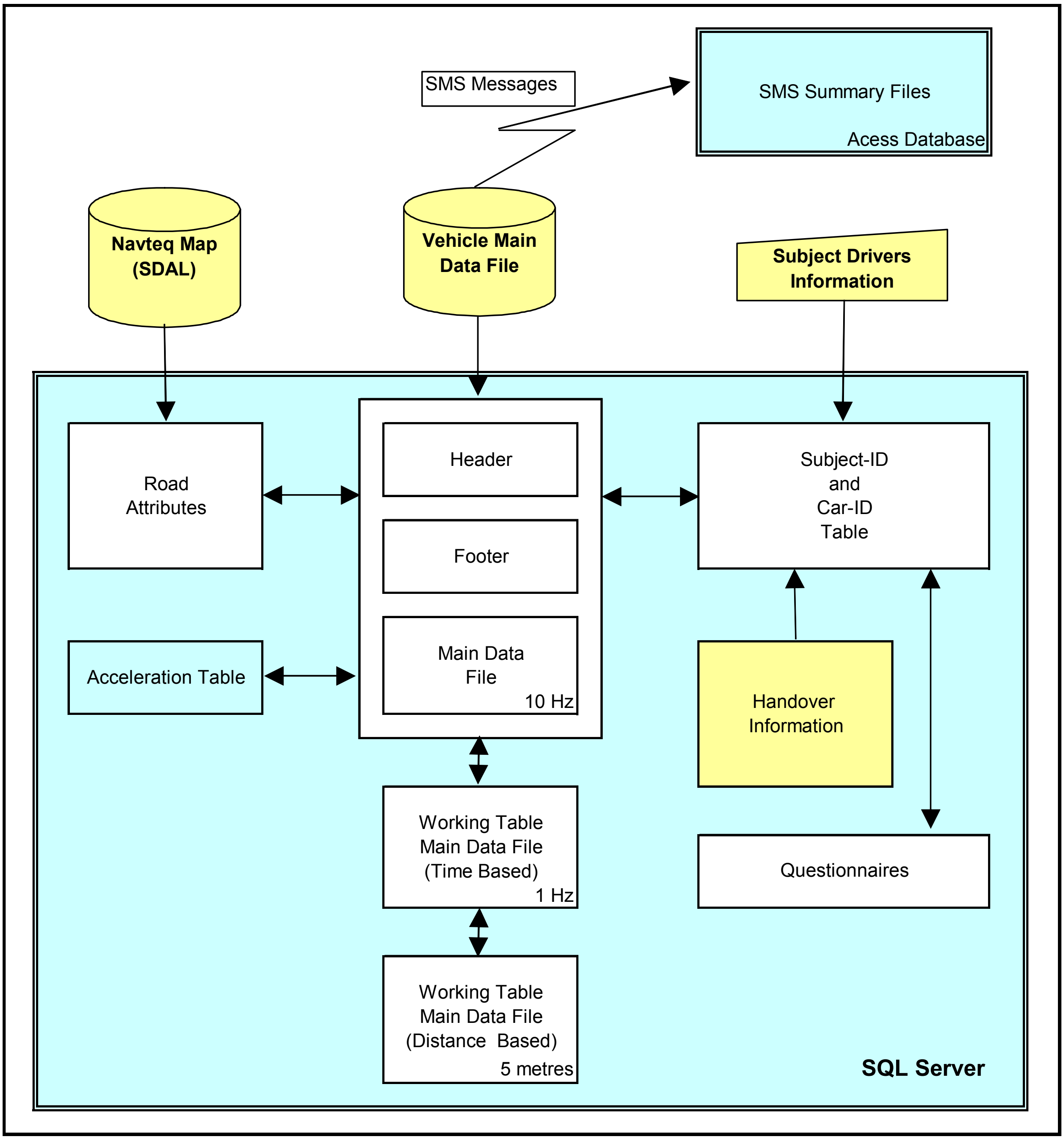


Figure 20: Structure of the data server

3.4 The digital speed limit map

The main requirements for the digital speed limit map were that:

- It needed to cover the Leeds Metropolitan District.
- It needed to be produced in a format that could be easily interpreted by the navigation company converting the map in to a real time version for use within the cars.

3.4.1 Coverage of the digital speed limit map

Leeds Metropolitan District covers an area illustrated in Figure 16. The area is run by Leeds City Council and it was their Highways Department that supplied the speed limit information in the form of paper files containing Council Speed Orders. The Leeds Metropolitan District is made up of 1890.09 miles of road. Table 13 describes the length of road for each road type with the majority road type being unclassified and the smallest type dual carriageway trunk roads.

Table 13: Breakdown of length of road in the Leeds Metropolitan District

Road Type	Total length (miles)
Motorway	42.25
Dual Trunk	8.08
Single Trunk	28.46
A Dual	38.09
A Single	109.92
B	44.12
C	93.33
Unclassified	1525.84
Total for all road types	**1,890.09**

Speed limits ranged from 20 mph to 70 mph within Leeds Metropolitan District. Figure 21 shows the distribution of speed zones on the digital speed map, which indicates that the majority of the roads in the Leeds trial area were 30 mph. Figure 22 is a snapshot of the digital speed map, which clearly highlights the dominance of 30 mph roads as well as six 20 mph zones.

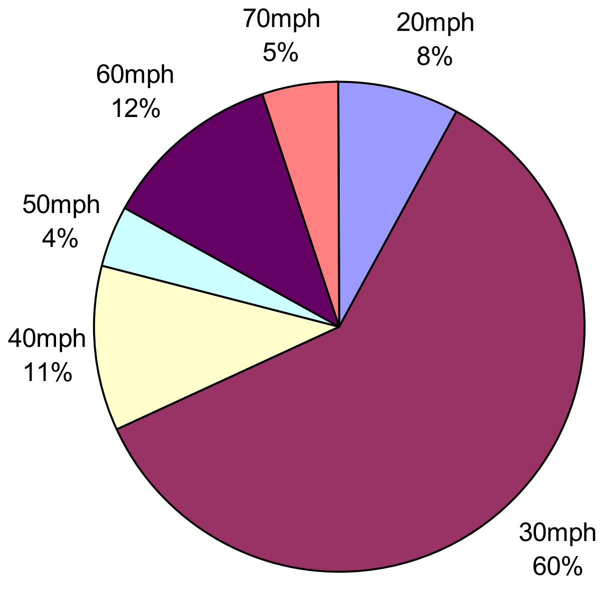


Figure 21: Distribution of speed zones in Leeds Metropolitan District

The council supplied the street data in the form of OSCAR Asset-Manager shape files containing data released in November 2001. OSCAR Asset-Manager is an Ordnance Survey data product that provides a digital representation of the Road network of Great Britain derived from the Ordnance Survey ROADS database. OSCAR Asset-Manager has centrelines of all publicly accessible and maintained roads. Private and pedestrian roads have been included where possible (Ordnance Survey, 2001). The digital street map has 1m accuracy. The Council supplied the vector data in a link and node structure – where links are road centrelines and nodes are intersections of links, with attributes attached to each feature (Burrough and McDonnell, 1998).

3.4.2 Implementation

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

The digital speed map that was sent to Navteq, the navigation company chosen for this project, was made up of two layers. The OSCAR Asset-Manager links layer represented by lines and the speed limits layer represented by points. The speed limits layer was constructed using the Leeds City Councils Speed Order files and the ArcInfo programmes ArcCatalog and ArcMap. The links layer already has an attribute table constructed, which was used as a template for the attribute table within the speed limit layer.

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

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

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

The speed limit layer required an attribute table to be constructed. Table 14 describes the attributes chosen. The initial structure was kept the same as the links attribute table, with the column headings chosen kept the same to aid Navteq in linking the layers together.

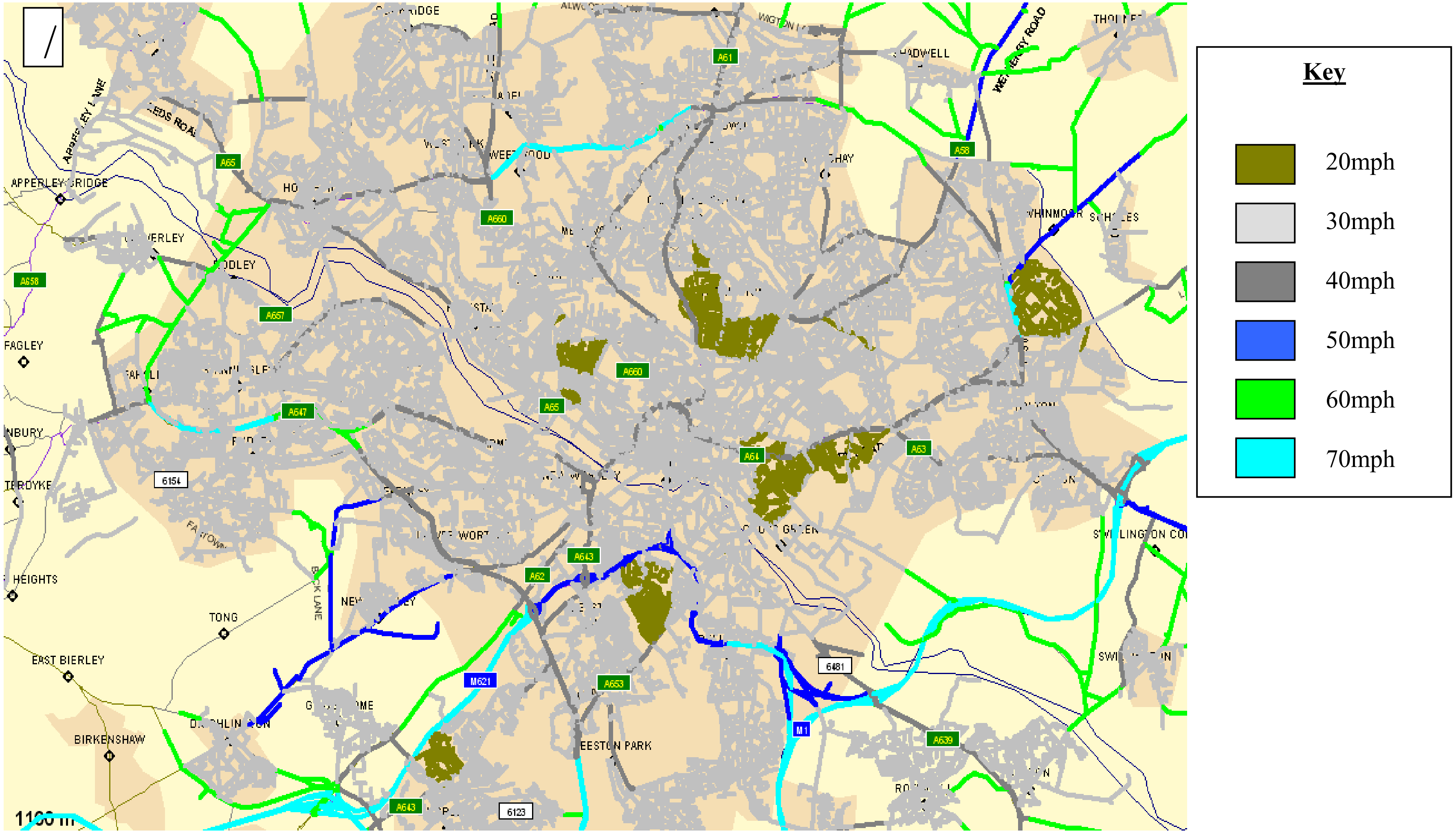


Figure 22: A map to illustrate the speed limit distribution within the Leeds Metropolitan District

Table 14: Description of the attribute table for the speed limit layer

Heading Name/ Description	Type	Length/Precision/Scale
FID (Feature ID Number)		
Shape (Point data)		
OS_NAME (Ordnance Survey Road Name)	Text	Length 25 Characters
OS_USRN (Unique reference Number)	Long Integer	8 Precision
OS_ODR (Unique Link Identifier)	Text	Length 20 Characters
OS_FC (Feature Class)	Short Integer	4 Precision
OS-LL (Length of Road Section)	Long Integer	5 Precision
OS-RN (Road Number i.e. A65)	Text	Length 10 Characters
OS-FW (Form of Way)	Text	Length 5 Characters
X_COORD (X Co-ordinate)	Double Integer	17 Precision, Scale 5
Y_COORD (Y Co-ordinate)	Double Integer	17 Precision, Scale 5
VALUE (Speed Limit)	Short Integer	5 Precision

3.4.3 Reliability

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

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

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

When the real time speed limit map came back from Navteq it was checked against the Speed Order information originally collected. Navteq had also included speed limits for all motorways and trunk roads within England, Scotland and Wales. The speed limit map was loaded on to the cars' operating equipment and field checks were carried out to ensure the speed limits changed as close to speed signs as possible.

In the event of a speed limit changing during the trial the capability to change the limit was available. However should a sign have moved position it was not possible to break the link to reposition the speed sign, resulting in the cars changing speed either earlier or later than the sign on the road.

3.5 Hypotheses

A number of hypotheses were established at the design stage of this project. These hypotheses are described below and are subsequently verified through the analysis chapters.

The ISA system designed for this project is default to be engaged but user overridable. Hence, it can be regarded as a mandatory ISA system with opt-out functionality. As a result, it is expected that the ISA system will not only diminish the mean speed but also transform the shape of the speed distribution, as illustrated in Figure 23 (Carsten and Tate, 2000).

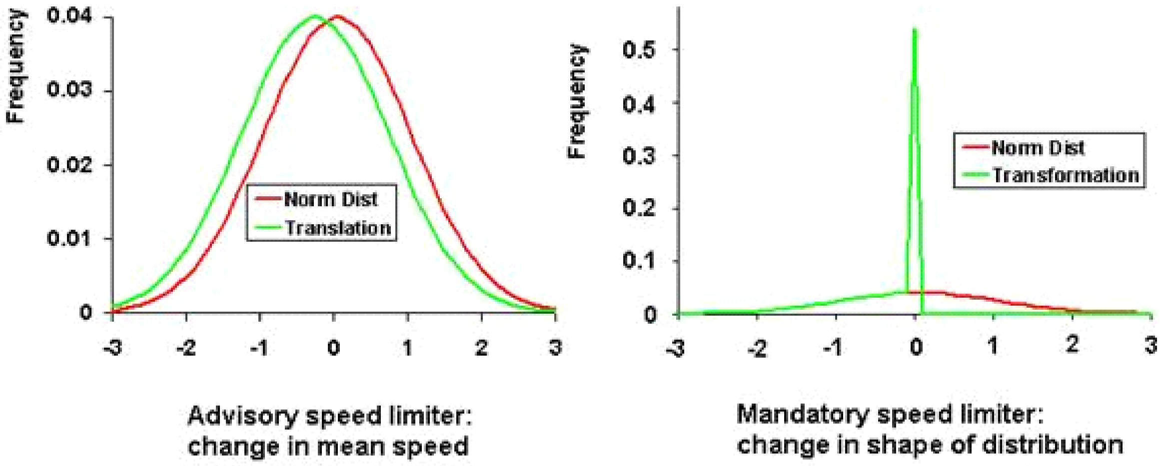


Figure 23: Theoretical effect of advisory and mandatory ISA on the speed distribution

Vehicle speed closely relates to the occurrence of accidents and severity of injury. For example, Taylor et al (2000) have demonstrated through empirical modelling that accident frequency is strongly correlated with mean vehicle speed and speed variation. It is therefore expected that ISA will contribute to a reduction in accident occurrence and injury severity by diminishing the mean speed and the high percentiles of the speed distribution as well as speed variation due to reshaping the speed distribution.

Hypothesis: Mandatory ISA will reform the shape of the speed distribution.
Hypothesis: With ISA, the speed distribution will be transformed by cutting the right end of the distribution, thus reducing the dispersion of the speed distribution.

Due to reduced speed variations in daily driving, it is also expected that fuel efficiency may be enhanced when ISA is activated.

Hypothesis: ISA will lead to better fuel economy.

It is expected that participants will show a safer driving style when ISA is activated due to elimination of excessive speed.

Hypothesis: With ISA, drivers improve their driving performance with respect to safety.

Apart from the expected effects of ISA on individual drivers' behaviour, it is also of interest to investigate the potential contribution of the ISA system to the entire road network. It is expected that, with 100% ISA penetration (i.e. mandatory ISA is rolled out nationwide), the traffic flow will form a platoon with stable headways, which will lead to reduced speed variation across the entire road network.

Hypothesis: ISA will increase traffic flow stability.

4. ANALYSIS OF QUESTIONNAIRE DATA

4.1 Introduction

In both the laboratory and real-road drives in the EVSC project, participants were considerably more hostile to mandatory ISA than to voluntary ISA. This hostility was somewhat reduced after driving with the system, but was by no means eliminated (Comte, 1999).

It is unlikely that Mandatory ISA could be introduced without general public support. Currently, opinion regarding such a system is not particularly favourable. According to the 1998 Lex survey of British motorists, 27 percent of the driving public would find automatic adjustment of speed to the prevailing limit to be very useful, as compared to 54 percent finding systems warning of congestion or bad weather to be very useful (Lex, 1998). In the 1997 survey, 17 percent of the responding drivers supported the installation of speed limiters on cars. This number compares with 24 percent supporting more speed bumps and 55 percent supporting the wider use of speed cameras (Lex, 1997).

However, it should not be forgotten that, prior to the introduction of legislation for the compulsory wearing of seatbelts in front seats, there was considerable opposition to the measure. Public opinion was only won over during the consequent media debate. Traffic calming has gone through a similar change: when first introduced it was widely opposed by local residents; now it is demanded by residents and tolerated by drivers.

There are also more theoretical grounds for believing that behavioural measures may be able to change attitudes. Spanish research on drink-driving, applying the Theory of Reasoned Action (Fishbein and Ajzen, 1975), has shown that beliefs about the consequences of driving under the influence of alcohol become more favourable with the frequency of driving under the influence in the previous six months. Similarly, drinking intensity was shown to make attitudes towards driving under the influence more favourable (Tejero Gimeno et al., 1997). From this one can conclude that *habituated behaviour* influences *attitudes* rather than the other way round, i.e. people construct a set of attitudes to justify their normal behaviour.

From this, it is possible to hypothesise that, with long-term exposure to ISA; driver attitudes will become more favourable. If confirmed, this could be a very important pointer to changes in public attitudes with increasing exposure to voluntary ISA. It could also be an important contribution to the continuing debate of how best to reduce driver propensity to commit violations on the road.

The Theory of Planned Behaviour (TPB: Ajzen 1985, 1988, 1991) was therefore used as a model for evaluating changes in attitudes to speeding and ISA as result of using the system for an extended period of time.

The TPB provides a parsimonious, deliberative processing model (Conner and Sparks, 1996) which advocates that intentions and perceived behavioural control (PBC) are the proximal determinants of behaviour. Intentions reflect the cognitive representation of an individual's readiness to perform a given behaviour (Ajzen, 1991). PBC describes the individual's perception of the ease or difficulty of performing any given behaviour (Ajzen, 1991).

As intentions and PBC are held to be direct antecedents of behaviour, the model also states that intentions are influenced by three additional factors. Attitudes, subjective norms and PBC are direct determinants of intentions:

- Attitudes towards a behaviour reflect the degree of positive or negative evaluation the individual has towards performing the behaviour.
- Subjective norms refer to the perceived social pressure to engage or not engage in a behaviour. These are understood to be the sum of normative beliefs concerning what salient referents believe about the individual enacting the behaviour, weighted by the individual's motivation to comply with this group, summed across the salient referents.
- PBC again reflects the perceived ease or difficulty of undertaking a given behaviour. An individual's perception of control is assumed to be the product of the individual's evaluation of factors likely to facilitate/inhibit the performance of a behaviour and the frequency of their occurrence. These control beliefs can be both internal and external in their nature. As the relative importance of intentions and PBC in predicting behaviour can differ across behaviours and populations, so too can the importance of attitudes, subjective norms and PBC in the prediction of intentions.

Figure 24 provides a schematic representation of the TPB.

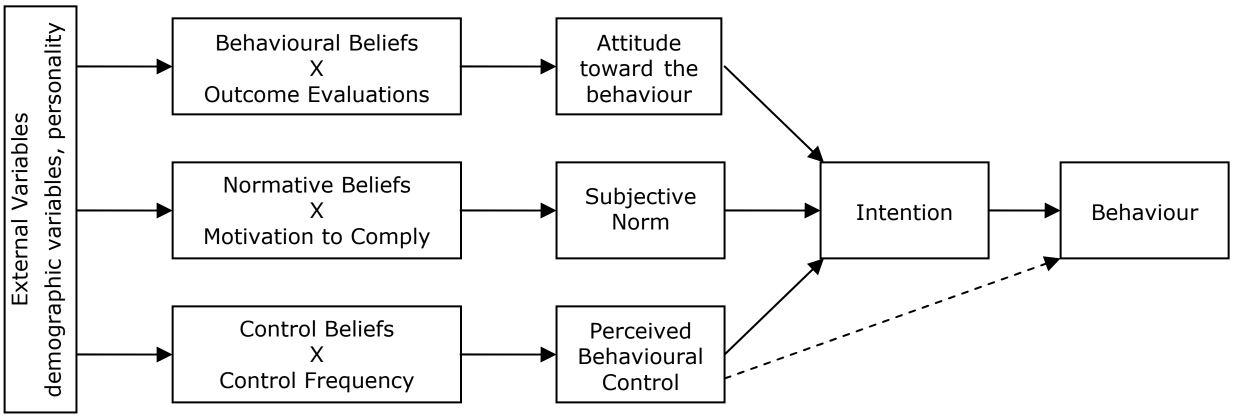


Figure 24: The Theory of Planned Behaviour (Ajzen, 1988)

Since the early 1990's research has examined the TPB and drivers propensity to speed (Lawton, Parker, Manstead and Stradling, 1997; Lawton, Parker, Stradling and Manstead, 1997; Parker et al., 1992a; Parker, Manstead, Stradling and Reason, 1992b; Parker, Stradling and Manstead, 1996), dangerously overtake (Parker et al., 1992a; Parker et al., 1992b; Parker, Manstead and Stradling, 1995), drink and drive (Parker et al., 1992a; Parker et al., 1992b), follow closely (Parker et al., 1992a; Parker et al., 1992b), recklessly weave (Parker et al., 1995), recklessly cut in (Parker et al., 1995), run red traffic lights (Manstead, Parker, Stradling and Lawton, 1996), flash at vehicles in front (Manstead et al., 1996) and engage in retaliatory/initiatory violations (Parker, Lajunen and Stradling, 1998).

Research within the driver behaviour domain has also sought to extend the TPB model, including variables such as past behaviour, moral norm and anticipated regret. Several authors have noted the impact of past behaviour upon subsequent behaviour. In a review of 12 intention related studies and five behaviour related studies, Conner and Armitage (1998) concluded that on average, past behaviour explained a further 7.2% and 13% of the variance in intentions and behaviour, respectively. Within the driver domain, habit has been reported as a strong predictor of intention to speed and reported speeding behaviour (Manstead and Parker, 1996). Elliot, Armitage and Baughan (2002) argue that habit may act as a moderator between TPB variables and behaviour, suggesting that drivers with a weak habit to comply with the speed limit base their intentions on attitudes, subjective norms and PBC to a greater extent than drivers with a strong habit to comply. Those such as Beck and Ajzen (1991) and Randall and Gibson (1991) advocate the inclusion of moral norm within the TPB model. Moral norm refers an individual's internalised moral rules or feelings of responsibility. The inclusion of anticipated regret (anticipated affective reaction to the behaviour; see van der Plight and de Vries, 1998b) has also received strong support. Parker et al. (1995) demonstrated that the addition of these personal norm measures improved the prediction of intention to cut in, recklessly weave and recklessly overtake by between 10.1% and 15.3%. Both moral norm and anticipated regret are believed to be especially relevant, since committing driving violations is a socially undesirable behaviour that may evoke anticipatory feelings of negative or indeed positive affect. Risk perception refers to an individual's evaluation of the risk involved in performing a given behaviour. An individual's perception of their societal role (i.e. their self-identity) has also been found to be independently predictive of individual intentions (see Conner and Armitage's review, 1998). To the best of our knowledge, the role of self-identity has not been assessed within driver behaviour research.

Speeding, unsurprisingly, has been the focus of several TPB studies. Parker et al. (1992a) concluded that the performance of the TPB was reasonable, explaining 49.1% of the variance in intention to speed. PBC was identified as the single most important predictor of intentions to speed. Drivers, particularly young males, demonstrated a lesser ability to refrain from speeding, reporting significantly weaker intentions and control over not committing the violation and perceiving significant others to have weaker negative expectations compared to their counterparts (Parker et al., 1992b). Speeding appears to be a social behaviour in which risks are based upon the individuals' perceptions of control and expectations of others and rather less on personal attitudes. Intentions to speed are held to be a function of the driver's assessment of the "reasonableness of a speed limit in a particular context" (Lawton et al., 1997, p. 162). The driver deliberately takes risks.

Primarily the TPB will used as a model to monitor changes in drivers' propensity to exceed the speed limit and disengage the system as a result of experience with ISA. Following the successful completion of all four field trials however, the sample size should also be sufficient to examine the proximal determinants of speeding. Although previous work has explored the theoretical underpinnings of the motivation to speed, conclusions drawn are based upon the prediction of intention to speed. To our knowledge, no previous study has examined the relationship between intention to speed and actual speeding behaviour in an instrumented vehicle. The link between intention and behaviour is certainly well documented (see Armitage and Conner, 2001) for other behaviours but the reliance upon self-report measures within the driver behaviour domain renders their validity subject to the question of social desirability bias. Although speeding has been socially constructed as a 'non-crime' (Corbett, 2000), within the experimental situation drivers may under or over estimate their involvement in speeding violations. The present project will test the predictive utility of the TPB with respect to speeding across three classes of road (motorway, urban, and residential roads) and the addition of measures of moral norm, anticipated regret, past behaviour, risk and self identity will test the sufficiency of the central components of the TPB model.

Analysis based on the first field trial however is limited given the small sample size and will thus concentrate on the change in key TPB constructs following experience of the ISA system.

4.2 Analysis on the Theory of Planned Behaviour

As mentioned earlier, completion of the four field trials will allow an evaluation of any changes in attitudes to speeding and ISA as a result of using the system and also test the predictive utility of the TPB. The sample size however is currently too small to attempt the latter. In order to examine changes in the TPB constructs over time and scenarios it would be most appropriate to perform a MANOVA. However given the limited sample this test would prove inappropriate. Comparisons have therefore been made across time on a construct by construct and scenario by scenario basis using a series of repeated measures ANOVAs. Although this test is regarded as more resilient, the sample size and between subject factors included (sex, age group, attitude group) compromise the results and make it difficult to draw any strong conclusions. Indeed any significant interactions have been suppressed and ignored since little meaning can be attributed to these. Constraints here also mean that it has been impossible to include other personality measures such as sensation seeking and conscientiousness. As the sample size increases from the subsequent trials the analysis will become more sophisticated and robust.

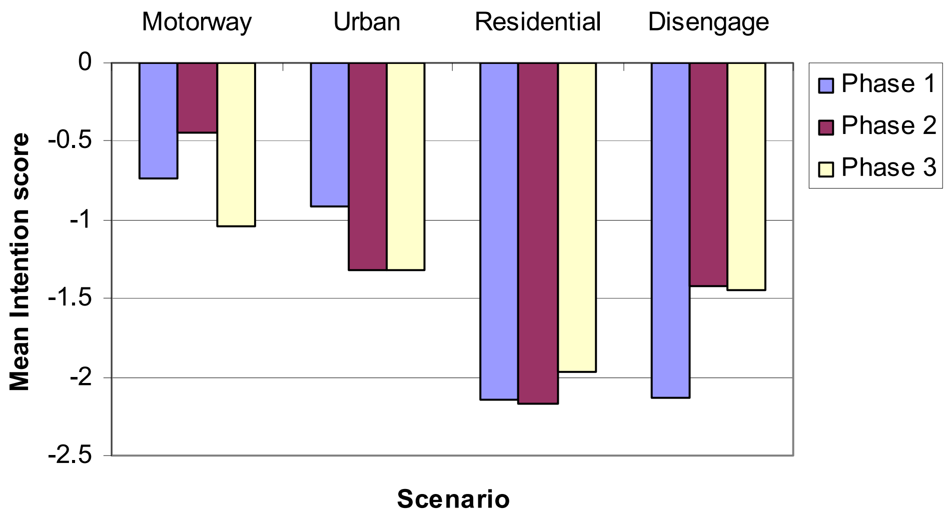


Figure 25: Mean intention scores by scenario

Figure 25 highlights the change in intentions over time for each scenario. The TPB proposes that intentions predict behaviour. There were no significant differences in intention scores over time for the motorway ($F(2,26) = 0.435$, $p = 0.652$), urban ($F(2,26) = 2.458$, $p = 0.105$), residential ($F(2,26) = 1.316$, $p = 0.258$) or disengage ($F(2,26) = 1.688$, $p = 0.205$) scenario. Although there is little effect of the ISA intervention several slight trends can be seen. Over time participants tended to express weaker intentions to exceed the speed limit on a motorway and urban road. Participants' intentions to exceed the speed limit were weakest for the residential road scenario where pedestrians and potential hazards are at their greatest. When ISA was available, intentions to exceed the speed limit decreased except for the motorway scenario where intentions increased. Results here may suggest that when restricted to 70mph drivers found the speed limit on UK motorways inappropriate and as such their intentions and desire to speed increased. During Phase 3, when drivers were allowed to drive at their desired speed, intention scores remained relatively stable compared to Phase 2. With respect to the system scenario, intentions to disengage the ISA system were very low during Phase 1 when drivers had no experience of the system. During Phase 2 and 3 intentions to disengage the system increased. It is uncertain why intentions may have increased as this could be due to frustration with the system or simply a response to the inaccuracies in the speed limit map database which meant that drivers overrode the system when false speed limits were displayed. Nevertheless, differences here were minimal and intention scores remained negative over time suggesting that the desire to override the system was weak.

Across all scenarios and time points, drivers held negative attitudes towards exceeding the limit. (see Figure 26). Again there were no significant differences in attitude scores over time for the motorway ($F(2,26) = 0.030$, $p = 0.970$), urban ($F(2,26) = 0.669$, $p = 0.521$), residential ($F(2,26) = 0.339$, $p = 0.716$) or disengage ($F(2,26) = 0.426$, $p = 0.658$) scenario. Again there was little effect of the ISA intervention. Differences across means are extremely small and little meaning should be attributed to these.

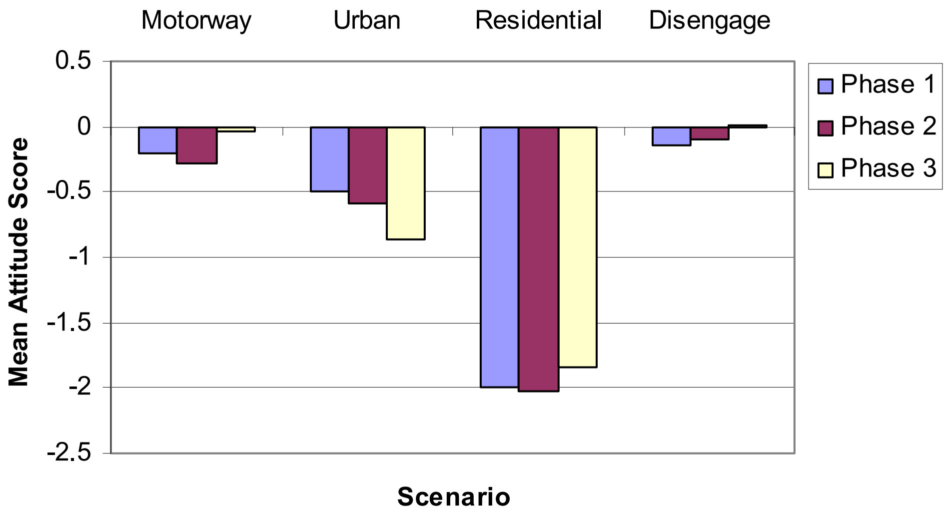


Figure 26: Mean attitude score by scenario

Behavioural belief scores provided an indirect measure of drivers' attitudes towards exceeding the speed limit and disengaging the system. Repeated measures ANOVAs did not reveal any significant differences over time for the motorway ($F(2,26) = 0.217$, $p = 0.806$), urban ($F(2,26) = 0.395$, $p = 0.677$), residential ($F(2,26) = 0.660$, $p = 0.525$) or disengage ($F(2,26) = 0.157$, $p = 0.855$) scenario. However it is of more interest to look at the individual behavioural belief scores rather than the composite mean scores in order to gain an overview of the beliefs that may be amenable to safety campaigns. Again however differences over time are minimal and interpretation should be treated with care.

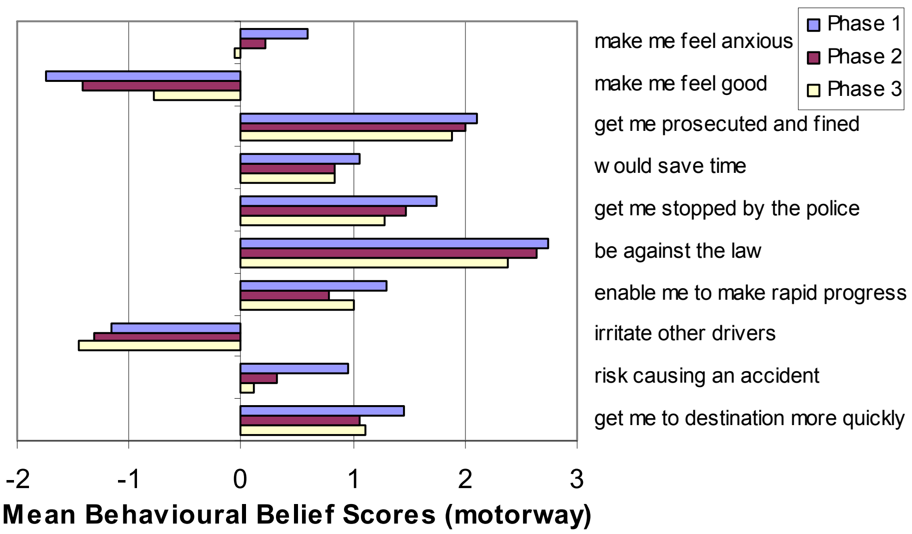


Figure 27: Mean behavioural belief scores for motorway scenario

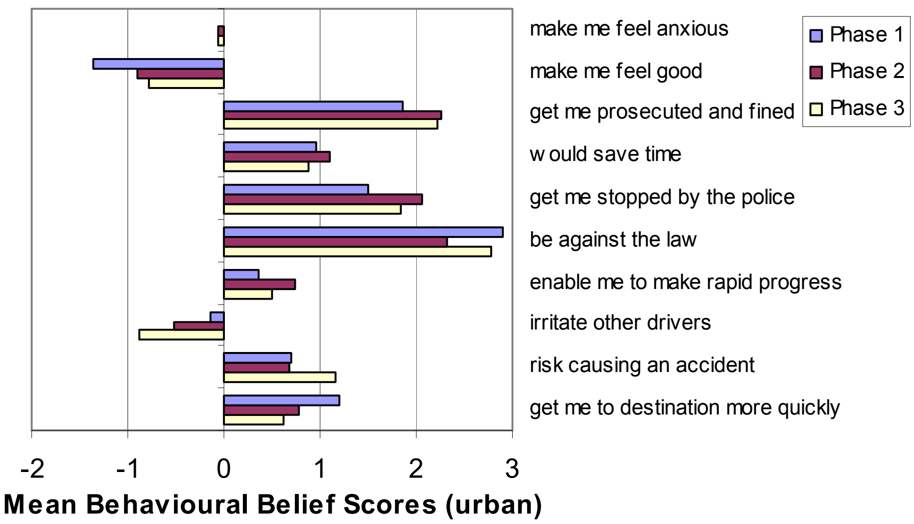


Figure 28: Mean behavioural belief scores for urban road scenario

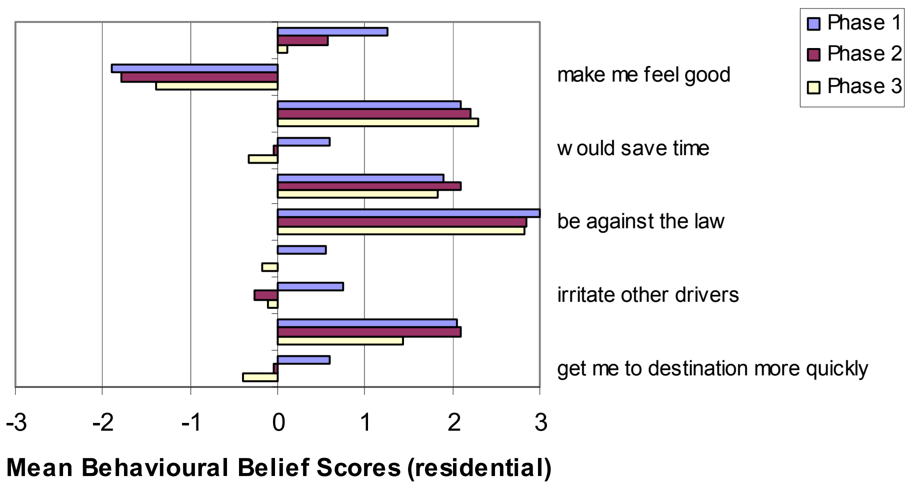


Figure 29: Mean behavioural belief scores for residential road scenario

Comparisons across the three speeding scenarios suggests that drivers belief that speeding would make them *feel anxious* was at its strongest during Phase 1, although they did not feel particularly anxious about speeding on an urban road — perhaps because this there are fewer hazards present in this environment. Following experience with the ISA system, drivers tended to believe that speeding would make them less anxious than they had previously thought. This may be a reflection of a change in the driver's definition of speeding. When initially answering the questions the drivers may have defined speeding as x% over the speed limit. However, since the system does not allow them to drive more than 1mph (except when travelling downhill) above the speed limit (and the speedometer reads only 10% above the limit) they may have redefined speeding and consider this much less dangerous. Initially drivers strongly disagreed that exceeding the speed limit would make them *feel good*, but, as the freedom to speed was withdrawn, drivers' beliefs weakened. Mean scores remained negative, but became less negative over time. Drivers appeared to realise that exceeding the speed limit did, in some ways make them feel good. Drivers' beliefs regarding *being prosecuted and fined* and *stopped by the police* can be considered together.

Figure 27, Figure 28 and Figure 29 suggest that following experience of the ISA system for the urban and residential scenario at least, drivers thought it more likely that speeding would lead to them being prosecuted and being stopped by the police, suggesting the system had heightened drivers' awareness of the legal implications of speeding. This was not true for the motorway scenario, perhaps because police presence and speed cameras are less obvious on this road type. Drivers' beliefs that exceeding the speed limit would *save time*, enable them to *make rapid progress* and *get them to their destination on time* generally tap into drivers perception of their journey times. For motorway, residential and in some part urban road scenarios, drivers beliefs generally weakened following experience with the system. Only in the urban scenario did drivers feel that exceeding the speed limit would save them time and allow them to make rapid progress. On the whole however, drivers experience with the ISA system educated them that driving above the legal speed limit does not necessarily reduce journey time. Drivers tended to believe that speeding in all scenarios would be less likely to be *against the law* following experience with the ISA system. This is somewhat at odds with their beliefs regarding prosecution and getting stopped by the police. Again the system may have challenged driver's definition of speeding and as such rationalised the small percentage that they exceed the speed limit as barely illegal. Having gained experience of the system drivers were less likely to believe that exceeding the speed limit would *irritate other drivers*. Generally drivers negative scores suggested that drivers did not believe that exceeding the speed limit would irritate other drivers and having experience of the system their beliefs were strengthened. It is highly likely that keeping within the speed limit may have served to irritate other drivers more than exceeding the limit. Overall drivers believed that exceeding the speed limit was likely to *risk causing an accident*. For the urban road and motorway scenario however, experience of the ISA system weakened this belief. Only in the residential scenario was this belief slightly strengthened. It may be suggested that when a drivers' speed was restricted they evaluated the higher speed limits as inappropriate and thus exceeding these limits was construed as less harmful.

Overall comparisons of these behavioural beliefs provide useful societal beliefs that can be encouraged and enhanced to reduce speeding and also negative beliefs that must be tackled and corrected.

Given that the behavioural belief scores for the disengage scenario range only from −1.3 to +1.35, any differences noted are minimal and beliefs are on the whole relatively neutral. The ISA intervention did not influence behavioural belief scores and trends shown below should be interpreted with caution.

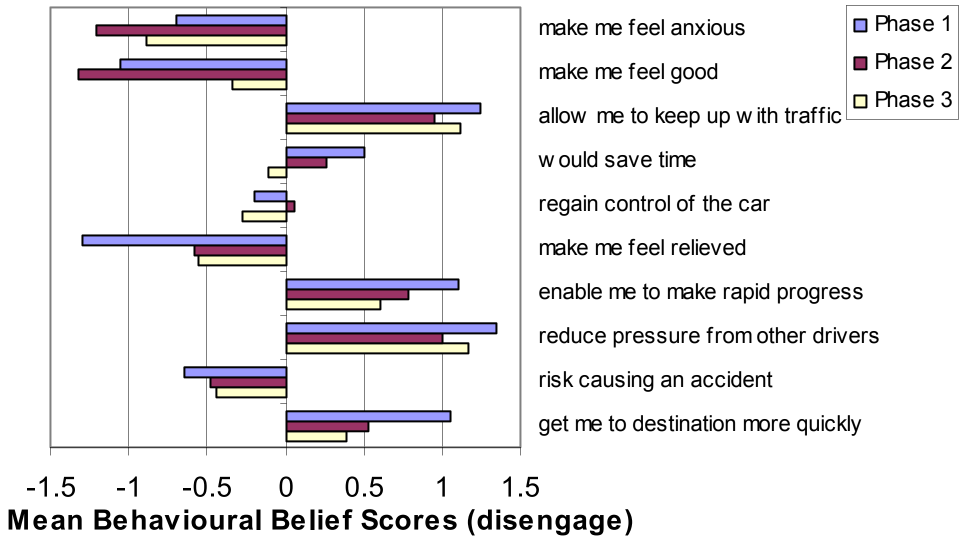


Figure 30: Mean behavioural belief scores for the disengage scenario

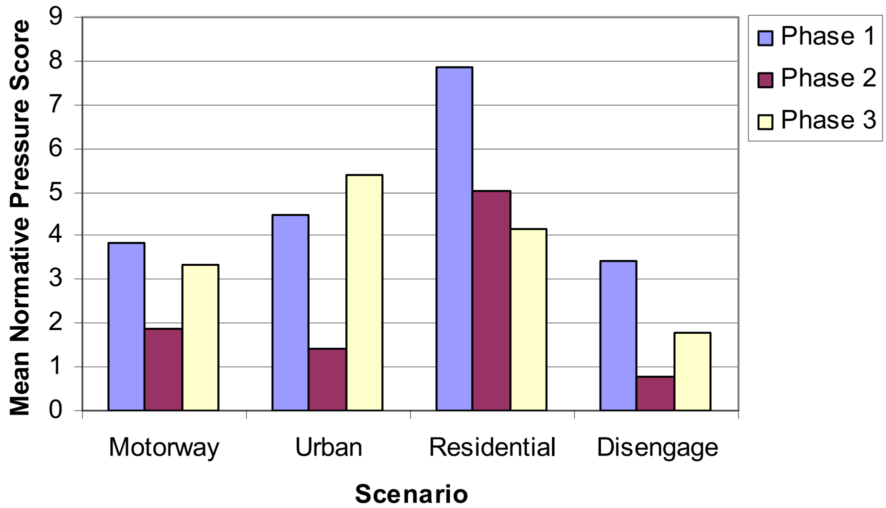


Figure 31: Mean normative pressure score by scenario

Perceived pressure from significant others decreased during Phase 2 and increased in Phase 3 for all scenarios (except the residential scenario). Whilst driving under the ISA control, drivers felt their significant other were less likely to disapprove of them exceeding the speed limit or disengaging the system. Differences may again be attributable to a shift in drivers' definition of speeding. They may have felt that significant others would disapprove of excessive speeding but when limited to the speed limit they may have felt that significant others would not have disapproved of driving a certain percentage above the speed limit. There were no significant difference in normative pressure scores over time for the motorway ($F(2,26) = 0.054$, $p = 0.947$), urban ($F(2,26) = 0.562$, $p = 0.562$), residential ($F(2,26) = 2.360$, $p = 0.114$) or disengage ($F(2,26) = 0.893$, $p = 0.422$) scenario.

Table 15: Mean motivation to comply scores over time

Referent Group	Phase 1	Phase 2	Phase 3
Police	5.50	5.53	5.89
Other road users	4.20	3.11	3.50
Family	5.60	4.79	4.61
Friends	4.05	3.84	4.28
Spouse/partner	5.35	4.74	4.72

As can be seen in Table 15, the Police and the driver's family were the most influential referents. It is important that drivers begin to believe that their significant others (i.e. the police, other road users, their family, other bikers) would disapprove of them exceeding the speed limit and that it is important to consider their beliefs when they are on the road. Implications for successful campaigns are discussed later.

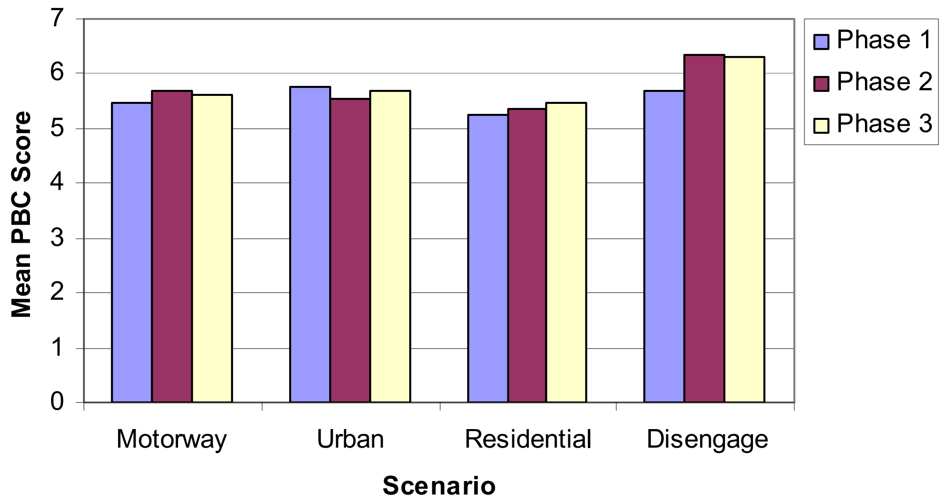


Figure 32: Mean perceived behavioural control score by scenario

Figure 32 generally shows an increase in drivers' perceptions of control during Phase 2 (except for the urban scenario). This is slightly surprising, because it was thought that driving with the system would have decreased drivers' perceptions of control. There were no significant differences in PBC scores over time for the motorway ($F(2,26) = 0.864$, $p = 0.433$), urban ($F(2,26) = 0.586$, $p = 0.564$), residential ($F(2,26) = 0.051$, $p = 0.950$) or disengage ($F(2,26) = 1.468$, $p = 0.249$) scenario.

Examination of control factor scores, i.e. indirect measures of PBC, confirms this increase in control over time (see Figure 33).

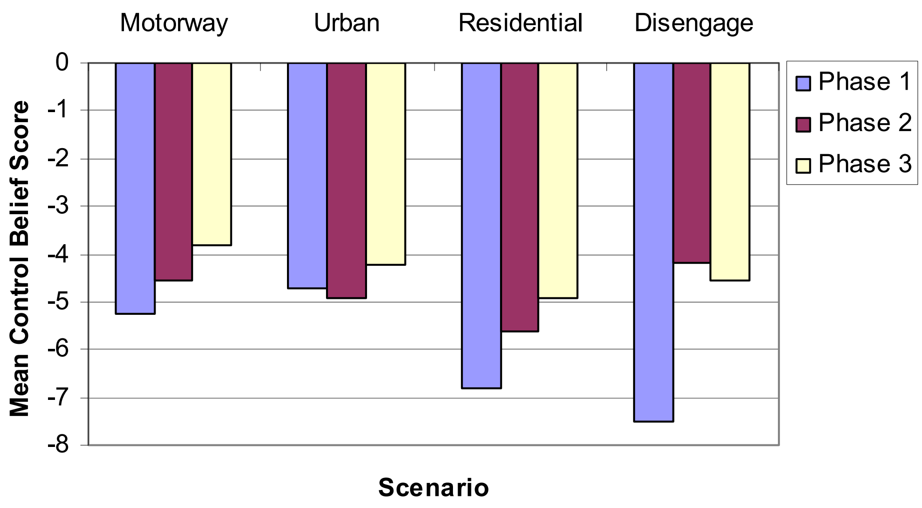


Figure 33: Mean control belief score by scenario

Figure 34, Figure 35, Figure 36 and Figure 37 provide a comparison of the stated control factors over time and scenarios.

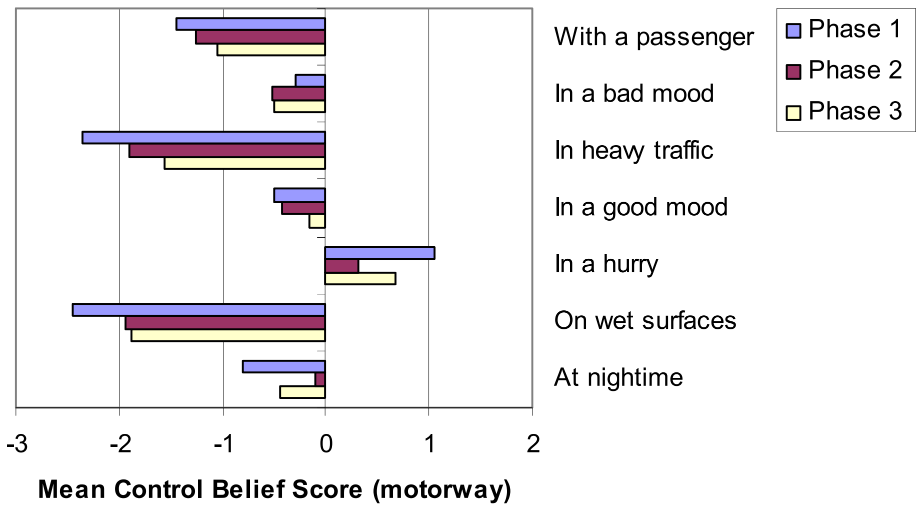


Figure 34: Mean control belief scores for motorway scenario

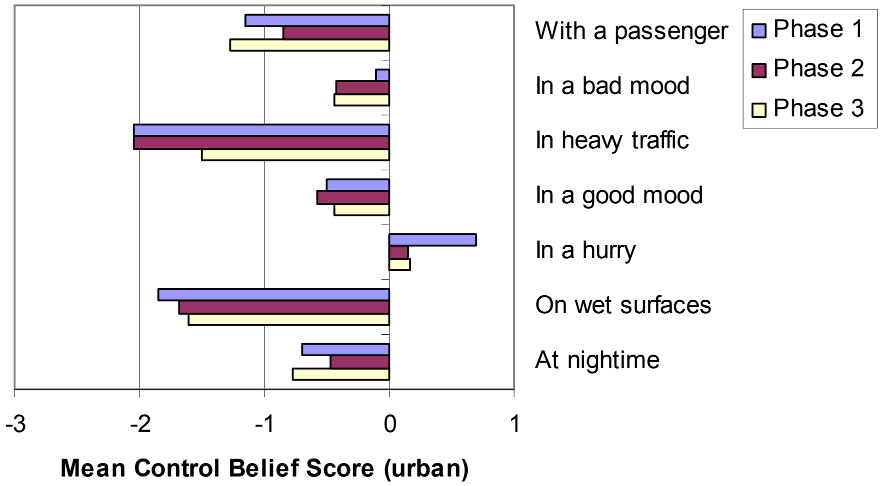


Figure 35: Mean control belief scores for urban scenario

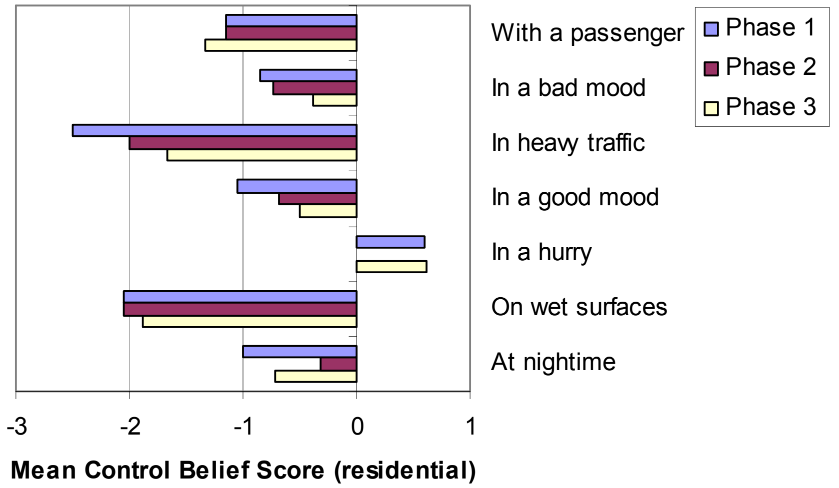


Figure 36: Mean control belief scores of residential scenario

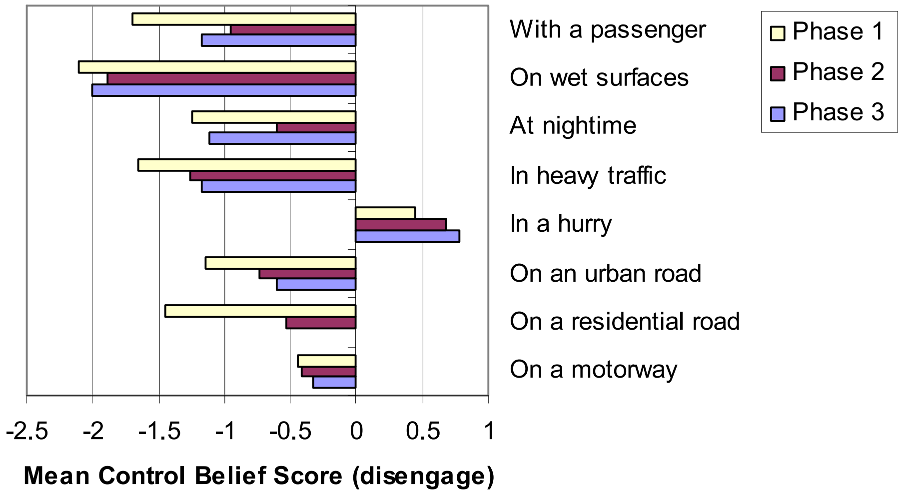


Figure 37: Mean control belief scores for disengage scenario

As can be seen the majority of control factors are generally seen as inhibiting drivers' propensity to speed and disengage the system, except for *being in a hurry* where this was seen to facilitate speeding and disengaging. Drivers felt they were more likely to speed and disengage the system when they were in a hurry. Across all scenarios, the majority of control factors were regarded as less inhibiting during Phase 2 when compared to Phase 1 and even less inhibiting in Phase 3. Being in a hurry was more likely to facilitate disengaging the system following exposure to the ISA system. During Phase 1 drivers felt that residential roads were the most inhibiting roads. They were less likely to disengage the system on these roads than any other road type. However, as can be seen in Figure 37, experience with the ISA system weakened this effect.

Generally the relatively high scores suggest that drivers believed that exceeding the speed limit across all scenarios and disengaging the system was morally wrong (see Figure 38). Moral norm scores during Phase 2 tended to remain the same for the motorway and residential scenarios but increased for the urban scenario and decreased for the disengage scenario. Indeed, although there were no significant differences in moral norm scores over time for the motorway ($F(2,26) = 0.098$, $p = 0.907$), urban ($F(2,26) = 1.239$, $p = 0.306$) and residential ($F(2,26) = 0.668$, $p = 0.521$) scenario, there was a significant difference in scores over time for the disengage ($F(2,26) = 5.695$, $p = 0.009$) scenario. Post hoc analysis revealed a significant difference between Phase 1 and Phase 3 scores. Drivers significantly weakened their belief that disengaging the system was morally wrong following prolonged exposure to the system.

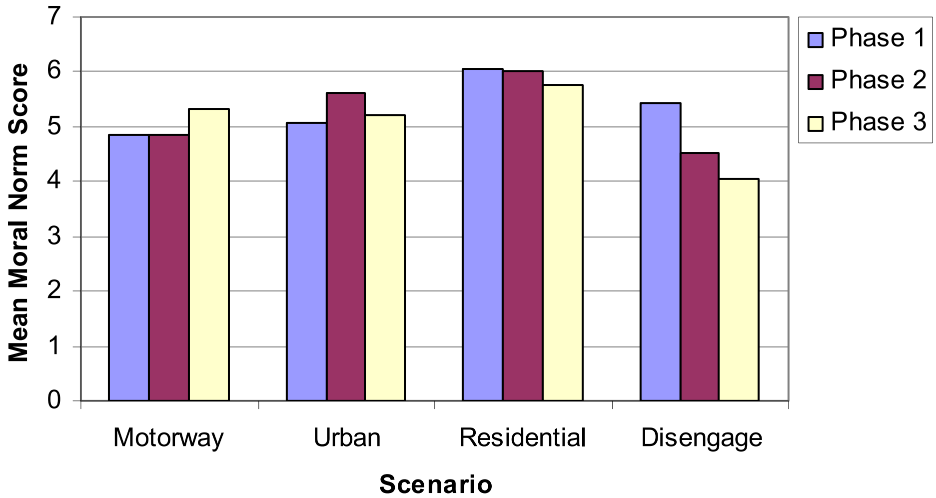


Figure 38: Mean moral norm score by scenario

Although drivers tended to believe that exceeding the speed limit was morally wrong, they did not tend to anticipate regretting engaging in this behaviour (see Figure 39). Although there were no significant differences in anticipated regret scores over time for the motorway ($F(2,26) = 0.346$, $p = 0.711$), urban ($F(2,26) = 0.816$, $p = 0.453$) and residential scenarios ($F(2,26) = 1.053$, $p = 0.363$), during Phase 2 drivers' ratings did tend to increase. This trend was not sustained through Phase 3. A significant difference for the disengage ($F(2,26) = 7.145$, $p = 0.003$) scenario was found. Post hoc analysis revealed that drivers anticipated experiencing significantly less regret after disengaging the system in Phase 2 and Phase 3 compared to Phase 1. Differences here may be attributable to the inaccuracies in the speed limit map, when indeed disengaging the system would prove a more comfortable option.

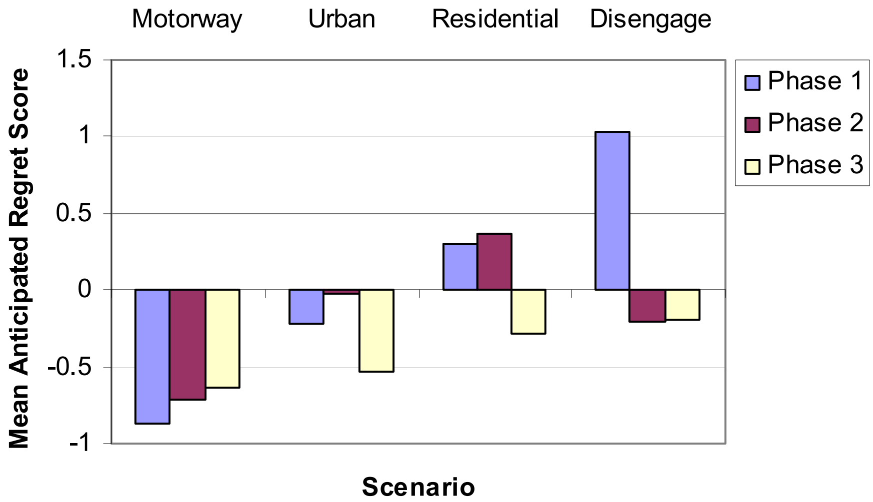


Figure 39: Mean anticipated regret score by scenario

Given the controlling nature of the system, past behaviour scores (see Figure 40) are as expected. Driver's self-reported propensity to exceed the speed in the last month decreased during Phase 2 (except for motorway which showed slight increase). For the urban and residential scenarios, self-reported speeding in Phase 3 increased but was still lower than that reported at Phase 1, suggesting that the effects of ISA may have been sustained throughout unsupported driving. For the motorway scenario, self-reported speeding remained the same. There were no significant differences in past behaviour scores over time for the motorway ($F(2,26) = 2.252$, $p = 0.125$) or residential ($F(2,26) = 1.218$, $p = 0.310$) scenario. However, there was a significant difference in past behaviour scores over time for the urban scenario ($F(2,26) = 7.890$, $p = 0.002$). Post hoc analysis revealed significant differences between Phase 1 and Phase 2 and Phase 1 and Phase 3 scores. Self-reported speeding on an urban road significantly decreased following experience with the ISA system, and this was sustained when the system was withdrawn.

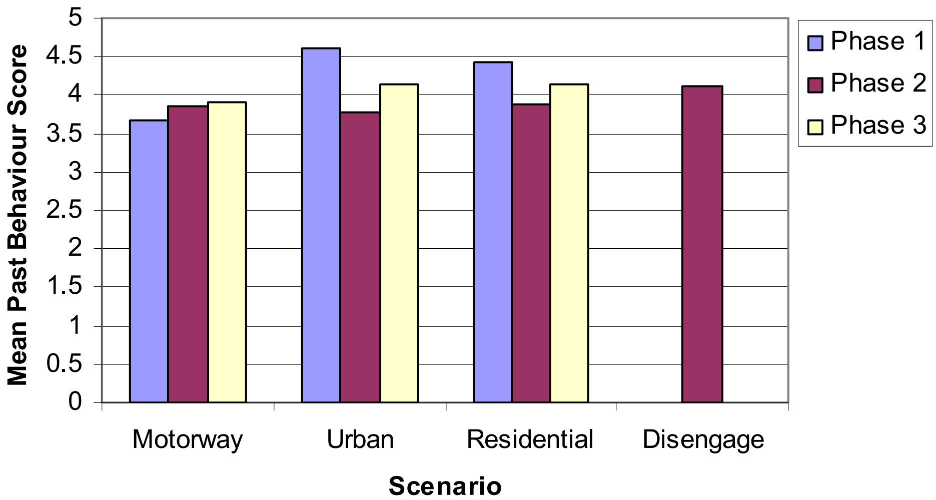


Figure 40: Mean past behaviour score by scenario

Comparisons of past behaviours can not be made with respect to disengaging the system since drivers had no prior experience of this technology. However it can be from Figure 40 that drivers had disengaged the system quite frequently in the past.

Figure 41 suggests that drivers' perception of the risk involved in speeding decreased during Phase 2 and continued to decrease during Phase 3. The trend of changes in mean scores suggests that experience of the system weakened their perception of risk. This may again be attributable to a change in drivers' perceptions of speeding. Since the system defines speeding as anything above the speed limit, driver may have considered this much less risky than what they had previously considered speeding. However these differences were not found to be significant for the motorway ($F(2,26) = 0.714$, $p = 0.499$), urban ($F(2,26) = 0.085$, $p = 0.919$), residential ($F(2,26) = 2.924$, $p = 0.072$) or disengage ($F(2,26) = 0.103$, $p = 0.902$) scenario.

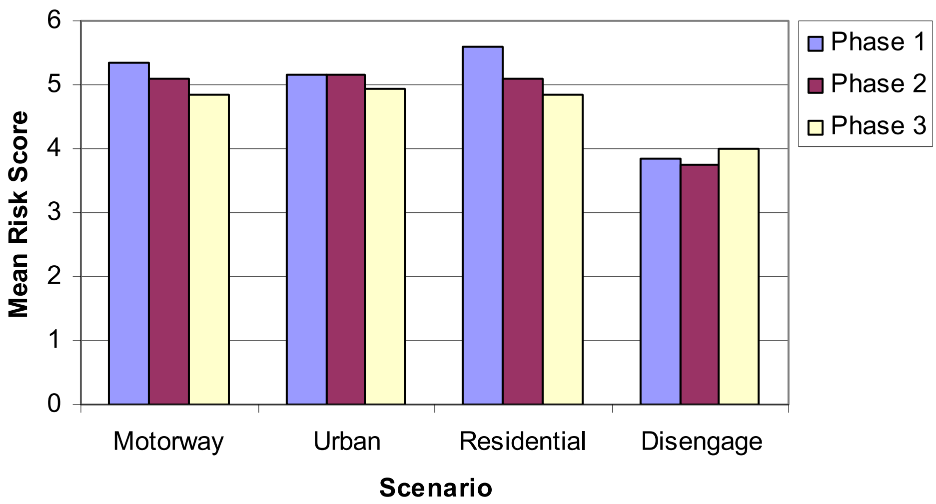


Figure 41: Mean risk score by scenario

Self identity measures were taken during each phase. As can be seen in Table 16, when driving under the ISA system drivers were slightly more likely to identify themselves as a safe driver. However this difference is minimal and there was no significant difference in scores over time however ($F(2, 26) = 0.214$, $p = 0.809$).

Table 16: Mean self-identity scores over time

Phase	Mean Score
Phase 1	5.78
Phase 2	6.11
Phase 3	5.94

Table 17: Correlation between TPB constructs and behavioural intention scores across time and scenarios

Construct	Phase 1 Correlations with Intentions				Phase 2 Correlations with Intentions				Phase 3 Correlations with Intentions			
	motorway	urban	Residential	disengage	motorway	urban	residential	disengage	motorway	urban	residential	disengage
ATT	0.624**	0.659**	0.586**	0.254	0.703***	0.740***	0.822***	0.310	0.667**	0.674**	0.713***	0.366
BE	0.538*	0.455*	0.274	0.198	0.658**	0.353	0.275	0.098	0.751***	0.647**	0.305	0.488*
NBMC	-0.701***	-0.523*	-0.652**	-0.143	-0.646**	-0.410	-0.501*	-0.572**	-0.671**	-0.591**	-0.382	-0.445
PBC	0.341	-0.100	0.278	-0.036	0.320	-0.095	-0.47	-0.069	0.248	0.106	-0.124	-0.231
CBF	0.614**	0.670***	0.527*	0.429	0.071	0.550*	0.537*	0.452	0.623**	0.626**	0.401	0.669**
MN	-0.646***	-0.352	-0.404	0.110	-0.603**	-0.416	-0.155	-0.444	-0.553*	-0.398	-0.402	-0.441
AR	-0.561**	-0.383	-0.430	-0.019	-0.540*	-0.396	-0.361	-0.477*	-0.516*	-0.276	-0.295	-0.386
PB	0.740***	0.438	0.473*	-	0.681***	0.212	0.283	0.352	0.693***	0.275	0.550*	-
RISK	-0.366	-0.547*	-0.326	-0.094	-0.387	-0.592**	-0.304	0.302	-0.493*	-0.705***	-0.176	-0.132
SI	0.031	-0.129	-0.394	-0.105	0.118	-0.196	-0.417	-0.099	-0.602**	-0.580*	-0.348	-0.355

Note 1: * denotes significance at the 0.05 level, ** denotes significance at the 0.01 level, *** denotes significance at the 0.001 level

Table 18: Correlation between behavioural intention scores across time and scenarios

	Motorway			Urban			Residential			Disengage		
	1	2	3	4	5	6	7	8	9	10	11	12
1. Motorway 1	-	0.445	0.625**	0.851***	0.374	0.647**	0.538*	0.579*	0.396	0.328	0.350	0.440
2. Motorway 2		-	0.603**	0.437	0.324	0.531*	0.123	0.325	0.306	0.184	0.353	0.303
3. Motorway 3			-	0.611**	0.574*	0.904***	0.244	0.364	0.541*	0.184	0.577*	0.656**
4. Urban 1				-	0.552*	0.704***	0.528*	0.755***	0.575*	0.541*	0.322	0.482*
5. Urban 2					-	0.706***	0.264	0.480*	0.677**	0.228	0.485*	0.636**
6. Urban 3						-	0.299	0.332	0.643**	0.215	0.483*	0.660**
7. Residential 1							-	0.641**	0.459	0.009	-0.085	0.155
8. Residential 2								-	0.655**	0.476*	0.267	0.332
9. Residential 3									-	0.455	0.396	0.689**
10. Disengage 1										-	0.062	0.224
11. Disengage 2											-	0.718***
12. Disengage 3												-

Note 1: * denotes significance at the 0.05 level, ** denotes significance at the 0.01 level, *** denotes significance at the 0.001 level

Table 17 provides a comparison of the TPB constructs significantly correlating with behavioural intentions over time and scenarios. There appeared to be little change in the significant correlates over time.

Generally, comparisons across time suggest that drivers intending to exceed the speed limit on a motorway tended:

- to possess more favourable attitudes towards exceeding the speed limit
- to believe that more positive than negative outcomes would result from exceeding the speed limit
- to perceive less normative pressure from significant others
- to believe that the stated control factors were more likely to facilitate rather than inhibit their exceeding the speed limit (except during Phase 2)
- not to believe that exceeding the speed limit was morally wrong
- not anticipate regretting exceeding the speed limit
- to have exceeded the speed limit frequently in the past
- to perceive less risk in exceeding the speed limit (except during Phase 1 and 2)
- to have a weaker self identity as a safe driver (except during Phase 1 and 2)

Generally, comparisons across time suggest that drivers intending to exceed the speed limit on an urban road tended:

- to possess more favourable attitudes towards exceeding the speed limit
- to believe that more positive than negative outcomes would result from exceeding the speed limit (except during Phase 2)
- to perceive less normative pressure from significant others (except during Phase 2)
- to believe that the stated control factors were more likely to facilitate rather than inhibit their exceeding the speed limit
- to perceive less risk in exceeding the speed limit
- to have a weaker self identity as a safe driver (except during Phase 1 and 2)

Generally, comparisons across time suggest that drivers intending to exceed the speed limit on a residential road tended:

- to possess more favourable attitudes towards exceeding the speed limit
- to perceive less normative pressure from significant others (except during Phase 3)
- to believe that the stated control factors were more likely to facilitate rather than inhibit their exceeding the speed limit (except during Phase 3)
- to have exceeded the speed limit frequently in the past (except during Phase 2)

Generally, comparisons across time suggest that drivers intending to disengage the system tended:

- to believe that more positive than negative outcomes would result from exceeding the speed limit (except during Phase 1 and 2)
- to perceive less normative pressure from significant others (except during Phase 1 and 3)
- to believe that the stated control factors were more likely to facilitate rather than inhibit their exceeding the speed limit (except during Phase 1 and 2)
- not anticipate regretting exceeding the speed limit (except during Phase 1 and 3)

Attitude, normative pressure and control beliefs were consistent significant correlates across time and scenarios. Attitudes were the most *consistent* correlate with intentions, proving a significant correlate in all speeding scenarios across time. Attitudes also tended to be the *strongest* correlate with intentions within scenarios suggesting their importance in any targeted safety campaign. Very few constructs significantly correlated with drivers' intentions to disengage the system.

Table 18 indicates significant correlations between all pairs of intention scores across time and scenarios. Significant correlations between motorway, urban and residential intention scores during Phase 1 indicated a shared variance of 72% and 29% respectively between the behaviours. This perhaps suggests that interventions targeted at speeding in general (through changing underlying beliefs) may be sufficient, rather than specifically adapting campaigns to particular road types. Intention scores for only the urban and residential scenario significantly correlated during Phase 1 and 2. Although the need for speeding campaigns ultimately declines with the introduction of an ISA system, the opt-out function incorporated allows the opportunity to speed and thus speeding still remains an issue. Any campaigns targeting speeding on a motorway and disengaging the ISA system when under the control of such a system cannot therefore rely upon those designed for speeding in a 'normal' car since the underlying beliefs differ. Moreover intentions scores across scenarios during Phase 2 did not significantly correlate, suggesting that interventions to reduce speeding in ISA cars that targeted speeding on all road types in general would only have modest impacts. It would therefore suggest the need for interventions to specifically target a particular road type.

Overview of the impact of ISA on the TPB constructs

On the whole results here should be treated with caution. Trends noted are based on very small differences in means and show little effect of the ISA system.

Generally for speeding scenarios drivers' intentions weakened during Phase 2 and 3. Comparisons of mean trends for the speeding scenario provide encouraging results that the physical enforcement of speed may be sufficient to change drivers' intentions. However no significant differences were found and thus conclusions are only tentative. For the disengage scenario drivers intentions strengthened. Inaccuracies in the speed limit database were discussed as a potential reason for this increase.

Attitudes correlated positively with intentions such that those drivers with more favourable attitudes towards speeding and disengaging the system were more likely to intend to exceed the speed limit and disengage the system. There was little effect of the ISA system on drivers' attitudes towards speeding. The trend in means did highlight that during ISA control drivers attitudes toward exceeding the speed limit became less favourable suggesting that the habituated behaviour imposed by the ISA system may have been sufficient to influence drivers' attitudes. However the effect was extremely modest and little value should be attributed to this trend. If such a trend was found significant in later trials however, this tentatively has important implications for the introduction of an ISA system throughout the UK given that prolonged use is adequate to change attitudes towards speeding and consequently attitudes towards the system. Although attitudes towards disengaging the system became more favourable, problems with the mapping software were discussed as possible explanations.

Behavioural beliefs correlated positively with intentions such that those who believed more positive outcomes would result from speeding or disengaging the system were more likely to intend to do such. Differences in behavioural beliefs over time are again minimal, but the direction of change in mean scores does hint at some possible target beliefs for intervention. Examination of the changes in behavioural beliefs identified several negative beliefs regarding speeding to be tackled. Compared with Phase 1, experience with the ISA system led drivers to believe that exceeding the speed limit was less likely to make them feel anxious, more likely to make them feel good, less likely to be against the law, less likely to irritate other drivers and less likely to lead to an accident. Several positive changes were also noted however. Following experience with the system, drivers were more likely to believe that exceeding the speed limit would lead to them being prosecuted and fined, stopped by the police and less likely to believe that speeding would save time, allow them to make rapid progress and get them to their destination on time. These results are encouraging in that the system weakened those beliefs regarding journey time and police enforcement, factors which are likely to be of great importance in today's society. Loss of money (through fines) and time are very influential factors and use of the system has imposed the risk of the cost and challenged and disproved critics concerns regarding increased journey time. In order to tackle the increase in negative beliefs, campaigns running during implementation should emphasise the negative emotive reactions to speeding, the direct link between speed and accidents and the power of the law to combat speeding. With respect to the disengage scenario, experience with the system led drivers to believe that disengaging the system was less likely to make them feel anxious, more likely to make them feel relieved, less likely to risk causing an accident and more likely to allow them to regain control of the cars. Campaigns should again tackle the emotive reactions associated with disengaging the system and comfort drivers, emphasising that the system still allows them to have control of their car and driving. Nevertheless experience with the system did weaken drivers' belief that disengaging would make them feel good and again challenged a key concern regarding journey time. Drivers were less likely to believe that disengaging the system would allow them to keep up with the traffic, save time, enable them to make rapid progress and enable them to get to their destination more quickly.

Subjective norms correlated negatively with intentions such that those who perceived less pressure from significant others not to exceed the speed limit or disengage the system were more likely to intend to do so. Perceived pressure from significant others regarding speeding and disengaging the system was also weakened during Phase 2, suggesting that drivers felt it was less likely important others would disapprove of these behaviours. It would therefore seem appropriate to raise drivers' awareness of the impact of speeding on their significant others. In view of the fact that the family and the police were the most influential referents, it is important that campaigns promote the importance of family, their disapproval of speeding and the potential impact of speeding on their lives. Steps should be taken to ensure police presence is directly or indirectly felt. Although direct policing may not always be appropriate, indirect measures such as speed cameras, police warning signs and information leaflets endorsed by the police might prove beneficial additions to any targeted campaign.

The inconsistent correlations between intentions and PBC make it difficult to discuss any relationships. Drivers' perceived behavioural control increased following experience with the system. This is somewhat at odds with our expectations.

Control factors positively correlated with intentions such that those who believed the stated factors were more likely to facilitate exceeding the speed limit or disengaging the system were more likely to intend to do such. Comparisons of the control factors suggests that following experience with the system drivers generally view these factors as less inhibiting than before. Campaigns should emphasise that driving with a passenger, in a good or bad mood, in heavy traffic, in a hurry, on wet surfaces and at night time are not excuses to exceed the speed limit or disengage the system. Indeed the consequences of these factors should be highlighted as important reasons not to do such.

Moral norms and anticipated regret correlated negatively with intentions such that who did not regard speeding and disengaging the system as morally wrong and those who did not anticipate regretting doing such were more likely to intend to perform these behaviours. For the speeding scenarios the presence of ISA did appear to affect drivers' personal norms such that they anticipated experiencing more regret after having exceeded the speed limit and tended to strengthen their belief that speeding was morally wrong. For the disengage scenario both moral norm and anticipated regret scores significantly dropped over time with experience of the system. Changes in personal norms here may be a reflection of inaccuracies in the speed limit map. Where the system displayed inaccurate and subsequently unsafe speed limits drivers are less likely to regret overriding the system as in most cases it is safer to do so.

Past behaviour positively correlated with intentions such that those who had frequently exceeded the speed limit in the past intended to do so in the future. As expected, past measures tended to decrease following experience with the system. This was inevitable given the controlling nature of the system.

Perceptions of risk on the whole were negatively correlated with drivers' intentions such that those perceiving less risk associated with speeding and disengaging the system were more likely to intend doing such in the future. Drivers' perceptions of the risk involved in exceeding the speed limit and disengaging the system slightly decreased following experience with the system. This was discussed in terms of changes in drivers' perceptions of speeding and uncertainty regarding the appropriateness of speed limits. Campaigns should seek to emphasise that exceeding the speed limit by only a small percentage can dramatically increase the risk of being involved in an accident.

Self-identity generally negatively correlated with intentions such that those who did not see themselves as a safe driver were more likely to intend to exceed the speed limit or disengage the system in the future. Experience of the system marginally raised drivers' perception of themselves as a safe driver. It would be of importance, therefore, to highlight the benefits of being a safe driver. Encouraging the formation of such a self identity is clearly a complex process but campaign which emphasised the positive aspects of this identity (e.g. thoughtfulness of others, calm) and countered the negative (e.g. carefree) might increase this self identity.

4.3 Driver Behaviour Questionnaire

The Driver Behaviour Questionnaire (Parker, Reason, Manstead and Stradling, 1995) measured the frequency with which individuals committed various types of errors and violations when driving, identifying three distinct types of aberrant driving behaviours; errors, lapses and violations. This questionnaire, administered at four time points, provided a self reported measure of changes in driving behaviour over the six month trial period.

Repeated measures ANOVAs were performed to identify significant differences in drivers' propensity to engage in aberrant driving behaviours as a result of the four month ISA intervention. Sex, age group and attitude group were included as between subject factors. Due to missing data, the analysis was carried out on 18 drivers. The results are presented in Table 19, Table 20 and Table 21.

Table 19: Analysis of variance for drivers' propensity to commit lapses

Factor effect	*F* statistic	*p* value
Time	F (3,39) = 0.582	0.630
Time × Sex	F (3,39) = 2.013	0.128
Time × Age Group	F (3,39) = 0.258	0.856
Time × Attitude Group	F (6,39) = 0.316	0.925

Note 1: * denotes significance at the 0.05 level, ** denotes significance at the 0.01 level, *** denotes significance at the 0.001 level

Note 2: 3 way interactions and above are ignored due to limited sample size

Table 20: Analysis of variance for drivers' propensity to commit errors

Factor effect	*F* statistic	*p* value
Time	F (3,39) = 6.511	0.001***
Time × Sex	F (3,39) = 1.467	0.239
Time × Age Group	F (3,39) = 0.900	0.450
Time × Attitude Group	F (6,39) = 5.383	0.000***

Note 1: * denotes significance at the 0.05 level, ** denotes significance at the 0.01 level, *** denotes significance at the 0.001 level

Note 2: 3 way interactions and above are ignored due to limited sample size

Table 21: Analysis of variance for drivers' propensity to commit violations

Factor effect	*F* statistic	*p* value
Time	F (3,39) = 12.152	0.000***
Time × Sex	F (3,39) = 3.557	0.023*
Time × Age Group	F (3,39) = 1.703	0.182
Time × Attitude Group	F (6,39) = 7.964	0.000***

Note 1: * denotes significance at the 0.05 level, ** denotes significance at the 0.01 level, *** denotes significance at the 0.001 level

Note 2: 3 way interactions and above are ignored due to limited sample size

The analysis revealed significant differences in drivers' error and violation scores over time as a result of the ISA intervention. Although there is no significant change over time in drivers' propensity to suffer lapses, these types of behaviour are generally considered less harmful, hazardous and thus less serious than committing errors and violations. Figure 42 shows that drivers propensity to suffer errors and violations significantly decreases over time. Post hoc analysis revealed a significant difference in error scores at time 1 and time 3 and time 1 and time 4. Prolonged experience with the system significantly decreased drivers' propensity to suffer errors and this was sustained when the ISA system was removed.

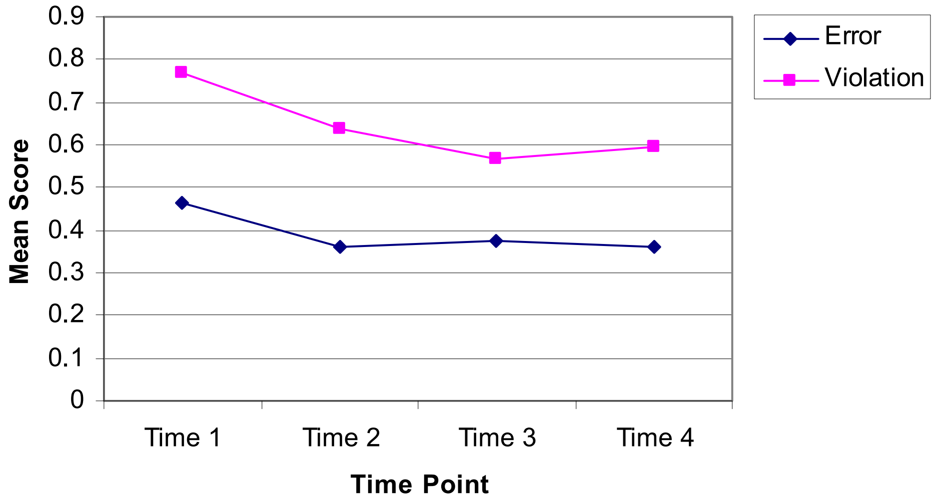


Figure 42: Mean error and violation scores on DBQ over time

As can also be seen in Figure 42, violation scores showed a slight increase at the final time point. However, post hoc analysis revealed a significant difference in violation scores at time 1 and time 2, time 1 and time 3 and time 1 and time 4 suggesting that immediate experience with the ISA system reduced drivers' propensity to commit violations and this effect was sustained when the support of the system was removed. These results have promising implications for future road safety interventions.

Significant interactions were also found, however given the limited sample size it is impossible to draw any meaningful conclusions from this data.

4.4 Acceptability

Driver acceptance of the ISA system was measured using an acceptability scale of advanced transport telematics developed by Van de Laan, Heino and De Waard (1997). This measure allows system evaluations across the dimensions of usefulness and satisfaction. As can be seen in Figure 43, drivers' usefulness and satisfaction ratings increased immediately with experience of the ISA system and continued to increase with prolonged experience.

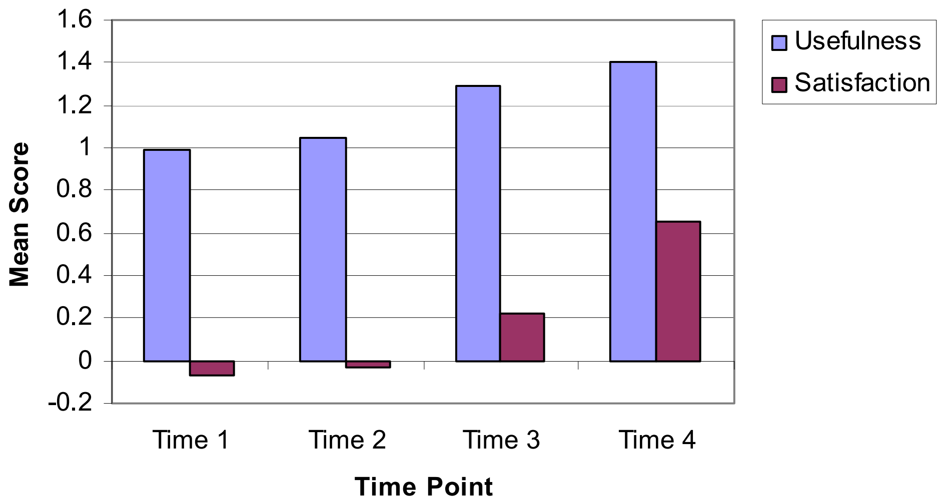


Figure 43: Acceptability ratings for the dimensions of "usefulness" and "satisfaction"

A repeated measures ANOVA (with sex, age group and attitude group as between subject factors) did not reveal a significant change in usefulness scores over time ($F(3,36) = 1.818$, $p = 0.161$). Nevertheless Figure 43 does suggest a definite trend such that as experience with the system increases, so too does drivers appreciation of the usefulness of such a system.

A repeated measures ANOVA (with sex, age group and attitude group as between subject factors) confirmed a significant change in satisfaction scores over time ($F(3,21) = 4.784$, $p = 0.007$). Post hoc analysis revealed a significant difference in time 1 and time 4 and time 3 and time 4 satisfaction scores suggesting that satisfaction with the system significantly increased when its support was removed. There were no significant interactions.

Prolonged driving experience with the ISA system increased drivers' appreciation of the system on the dimensions of usefulness and satisfaction. Interestingly drivers rating on both dimensions continued to significantly increase in the final month of driving without ISA. Results may suggest that the return to normal driving amplified the potential of ISA when drivers were left without the support of the system.

4.5 System design

Several items sought information regarding the design of the ISA system. Figure 44 and Figure 45 illustrate the most common cues within the system that drivers relied upon to inform them of system state changes throughout the 4 month ISA period.

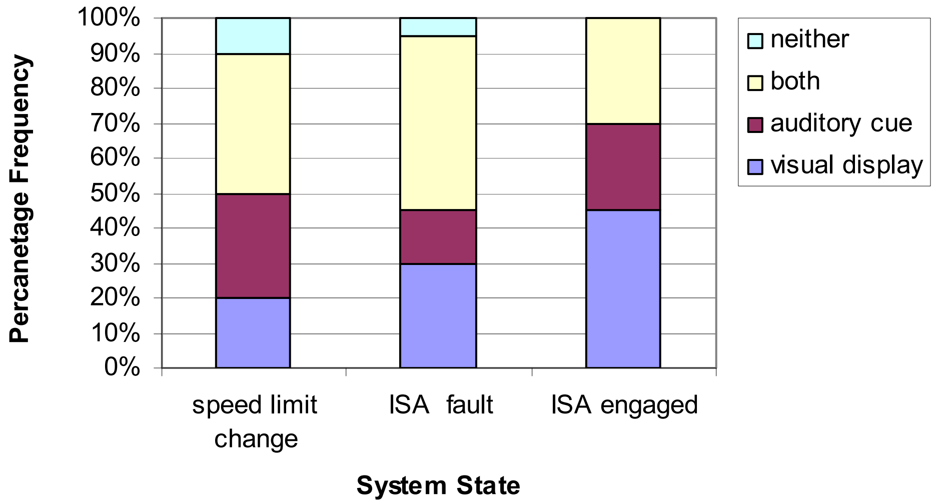


Figure 44: Most frequent cues relied upon for notification of system state changes during early exposure to ISA

There are very few differences in the way drivers used the ISA system cues as their experience with the system increased. The majority of drivers tend to use both the visual and auditory cues to inform them of system state changes.

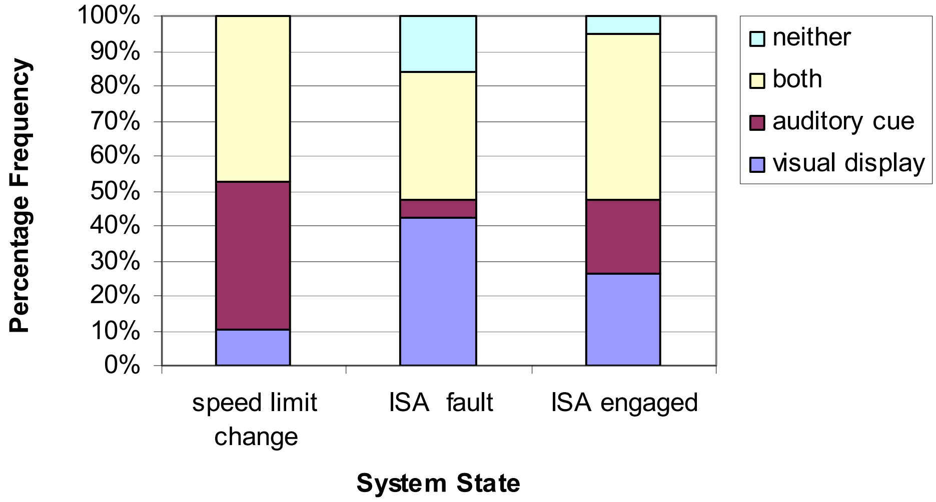


Figure 45: Most frequent cues relied upon for notification of system state changes following prolonged exposure to ISA

4.6 Stakeholder survey

As part of the European project PROSPER, a policy Delphi was used to gather detailed opinions on speed management and ISA systems from interested stakeholders in 8 European countries. A number of items taken from the first round of this stakeholder survey were administered to the test drivers to allow a comparison of the views of U.K experts and the general public. It should be noted however that the sample of test drivers is small and generalisations to public opinion should be treated with care. Nevertheless the results do provide some interesting comparisons between the two groups.

An initial question asked respondents who they thought ISA should be targeted at (all drivers without distinction, professional drivers, speed offenders, novice drivers or other groups). The respondents could choose more than one group.

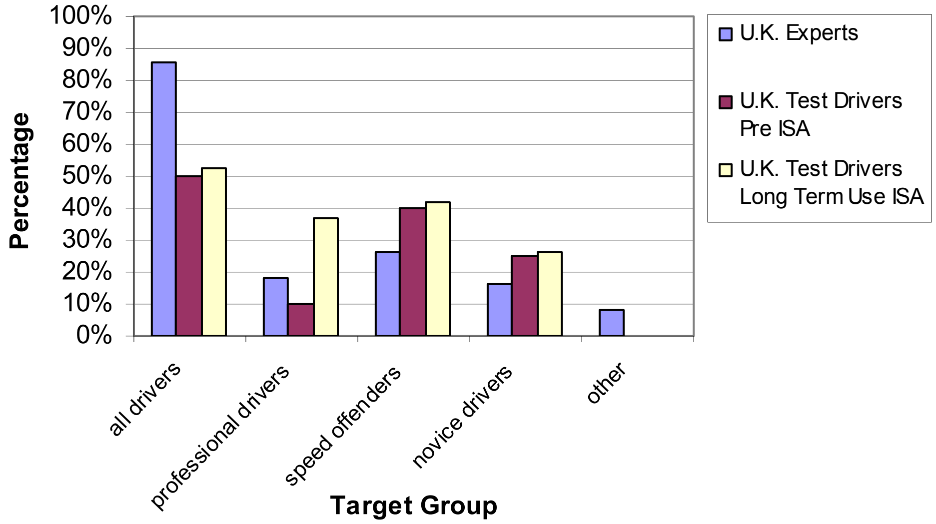


Figure 46: Target groups for ISA

Figure 46 highlights slight differences between the experts' and drivers' opinions regarding the suitability of ISA for certain user groups. Experts overwhelmingly opted for ISA all drivers, whereas only approximately 50% of the drivers felt that the system should be targeted at all drivers. Indeed drivers regarded ISA as more appropriate intervention tool for speed offenders and novice drivers. Whilst this is perhaps a difficult implementation path to follow and monitor, given that novice drivers often drive their parents car and the ease of purchasing a second car without ISA control, it does suggest that the general public may become more accepting of this type of control if it seen to be punishing offenders or educating novices rather than being forced upon the general public.

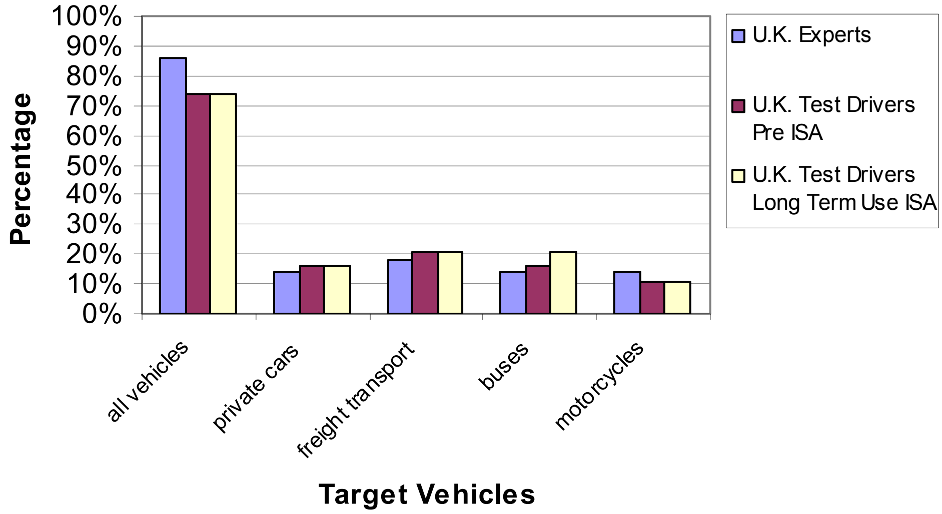


Figure 47: Target vehicles for ISA

Respondents were also asked which vehicles should have ISA installed. Drivers were allowed to select more than one option. Again Figure 47 shows little change in drivers' opinions following long term exposure to the ISA system. Drivers' opinions are much more in line with those of the experts, agreeing that ISA should be fitted to all vehicles. This however is somewhat in contrast with their previous concern regarding whether ISA should be targeted at all drivers. Figure 48 suggests that both experts and drivers are in favour of a fully ISA operationalised road infrastructure throughout the UK. For those who did not agree that ISA should be active for all road types, motorways and major roads outside built up areas were the road types regarded as least suitable for speed control, perhaps because these afford the greatest opportunity to break the speed limit.

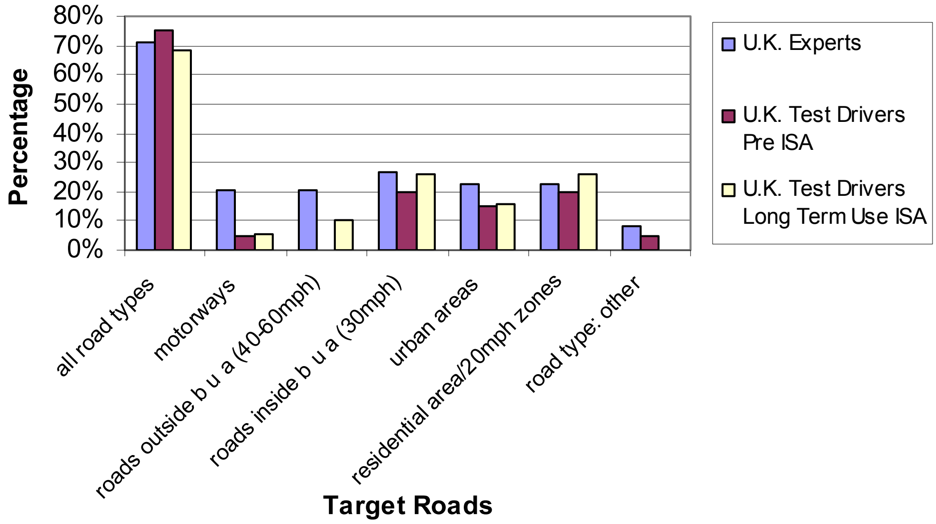


Figure 48: Target roads for ISA

5. ANALYSIS OF VEHICLE DATA

5.1 Introduction

This chapter presents analysis of vehicle data. Data completeness is reviewed in the next section, followed by analysis of trip based data, and analysis of vehicle speed. In addition to analysing speed distributions in individual speed zones, the effect of ISA intervention was also examined by demographic factors in terms of gender, age, and intention to speed.

5.2 Data completeness

As specified in Section 3.1, each participant was expected to generate 168 days of travelling data. Interruption to data collection was attributable to various ISA system failures. Thirteen out of the 20 participants had to be given replacement cars following a system failure which caused consequent interruption to data collection. Due to the technical difficulties, five participants were not able to contribute full 168-day data within the sustainable time frame. The overall completion rate was 96.7%, as shown in Table 22 and Figure 49. Data on the operational rate of the fleet is given in Appendix C.

Table 22: Data completeness in Field Trial 1

Participant ID	Completed days	Completion rate (%)
1	161	95.8
2	168	100
3	168	100
5	168	100
6	168	100
7	129	76.8
8	168	100
9	168	100
10	168	100
11	168	100
12	168	100
13	168	100
14	168	100
15	168	100
16	168	100
17	168	100
18	168	100
21	150	89.3
22	146	86.9
23	144	85.7
Overall completion rate		**96.7**

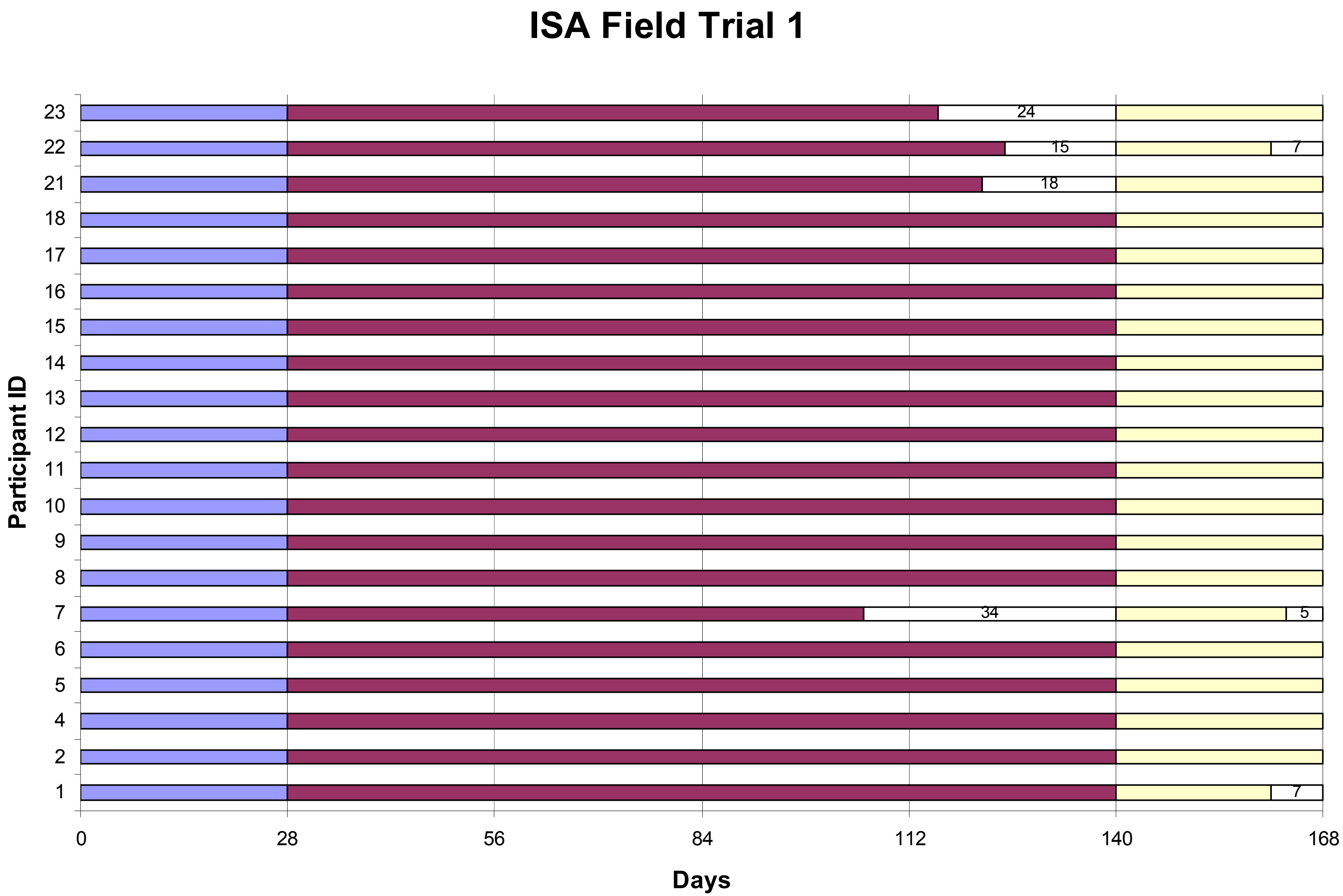


Figure 49: Completion rate in Field Trial 1

5.3 Analysis of trip based measures

Table 23 depicts the means and ANOVA test results of trip based measures. Trip duration, trip length, and fuel consumption all increased in line with the progress of the trial phases. There was however no statistical difference across trial phases with respect to trip duration and trip length. Fuel consumption derived from Phase 2 was not different from Phase 3, but they were both significantly different from Phase 1 ($p < 0.01$ in both t-tests).

Table 23: Statistical test results of trip based measures

Measure	Mean			ANOVA test results	
	Phase 1	Phase 2	Phase 3	F statistic	Significance
Trip Duration (minutes)	11.90 (3.02)	12.42 (3.31)	12.72 (2.71)	$F(2, 38) = 1.984$	0.151
Trip length (miles)	4.76 (1.64)	5.11 (1.89)	5.41 (1.71)	$F(2, 38) = 2.884$	0.068
Fuel consumption (MPG)	34.13 (3.02)	35.44 (3.00)	35.99 (3.06)	$F(2, 38) = 11.245$	< 0.0005**

Note: 1. Figures in brackets are standard deviation.
2. * denotes the difference is significant at the 0.05 level
3. ** denotes the difference is significant at the 0.01 level

While there is no definite evidence to suggest why these three measures increased in line with trial phases, seasonal difference in travel patterns might have contributed to such an interesting phenomenon, as most of the participants started their Phase 1 in winter or early spring and all participants finished their Phase 3 during the summer months. Based on the data obtained from Trial 1, no distinctive effect of ISA on trip duration, trip length, or fuel consumption was identified. However, further evidence may be revealed from the remaining three field trials.

5.4 Analysis of vehicle speed

5.4.1 Data processing

Although the data logging system in the vehicle generates data at 10Hz (i.e. 10 records per second), data used for analysis was distance based rather than time based. While time based data is intuitively valid, it introduces undue weight to the data stream when vehicle speed is zero (e.g. the vehicle stops at junctions) or very low (e.g. the vehicle moves slowly on a congested road). Conversion algorithms were therefore developed for extracting a record per 5 metres of travelling distance from the data stream. This data processing also filtered out records without a valid speed limit attached to them, attributable to the vehicle being driven on roads which were not given speed limits by NavTech, such as private roads (e.g. supermarket car parks) or non-trunk roads outside the Leeds area. The above process led to a data file containing nearly 30 million valid records, across all participants and trial phases, ready for analysis.

Weighting across participants to equalise individuals' contribution of travel distance during the trial to the data was considered in order to prevent the data from being possibly distorted by participants with high annual mileage. However, it was eventually decided not to apply weights to retain a valid representation of the sample against the whole driving population, as annual mileage inherently differs from one driver to another.

5.4.2 Vehicle kilometres

Following data processing and reduction, the final data file ready for analysis represents a total travel distance of 146,697 kilometres. A breakdown of vehicle kilometres with respect to speed zones is illustrated in Figure 50. The largest portion of vehicle kilometres was attributable to 30 mph zones, followed by 70 mph zones and 40 mph zones. Most of the vehicle kilometres were recorded in urban areas (i.e. 20, 30, and 40 mph zones, which contributed to 69.2% of total vehicle kilometres).

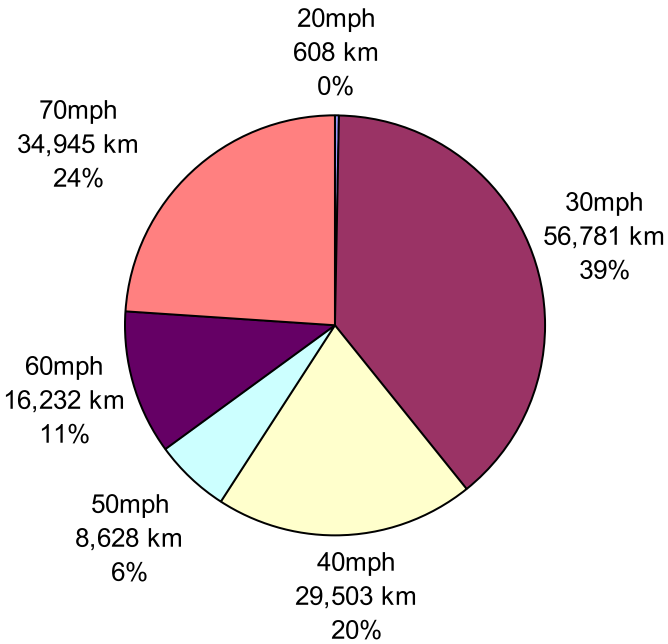


Figure 50: distribution of total vehicle kilometres with respect to speed zones

Table 24 provides a further breakdown of the proportion of vehicle kilometres within individual trial phases, which suggests that the contribution of each speed zones to the total vehicle kilometres remains very similar across trial phases, i.e. 30 mph zones always contributed the most, followed by 70 mph zones and 40 mph zones.

Table 24: Vehicle kilometres across trial phases

Speed zone	Vehicle Kilometre			Distribution based on trial phase		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
20 mph	123	380	104	0.5	0.4	0.4
30 mph	10,194	36,617	9,970	42.5	38.3	36.9
40 mph	5,073	19,074	5,356	21.2	19.9	19.8
50 mph	1,153	5,844	1,631	4.8	6.1	6.0
60 mph	2,158	11,339	2,736	9.0	11.8	10.1
70 mph	5,282	22,451	7,212	22.0	23.5	26.7
Sum	23,983	95,705	27,009	100	100	100

5.4.3 Speed distribution across trial phases

The logged vehicle data provides a comprehensive database of the speed distribution. The effect of ISA intervention on speed distribution was analysed with respect to the shape of the distribution coupled with statistical tests determining the significance of difference in speed distribution across trial phases. The difference between two speed distributions was examined by central tendency (e.g. mean, median, and mode) as well as key percentiles towards the right end of the distribution (e.g. the 85^{th}, 90^{th} and 95^{th} percentile).

The high percentiles of the speed distribution offer very useful information for inspecting the presence of speed violation, especially the 85^{th} percentile which closely corresponds to one standard deviation above the mean of a normal distribution. In addition, traffic engineers have commonly used the 85^{th} percentile of the speed of free flow traffic for determining speed limits. Therefore, a reduced value of the 85^{th} (as well as the 90^{th} and the 95^{th}) percentile of the speed distribution would be an indication of diminished speed violation.

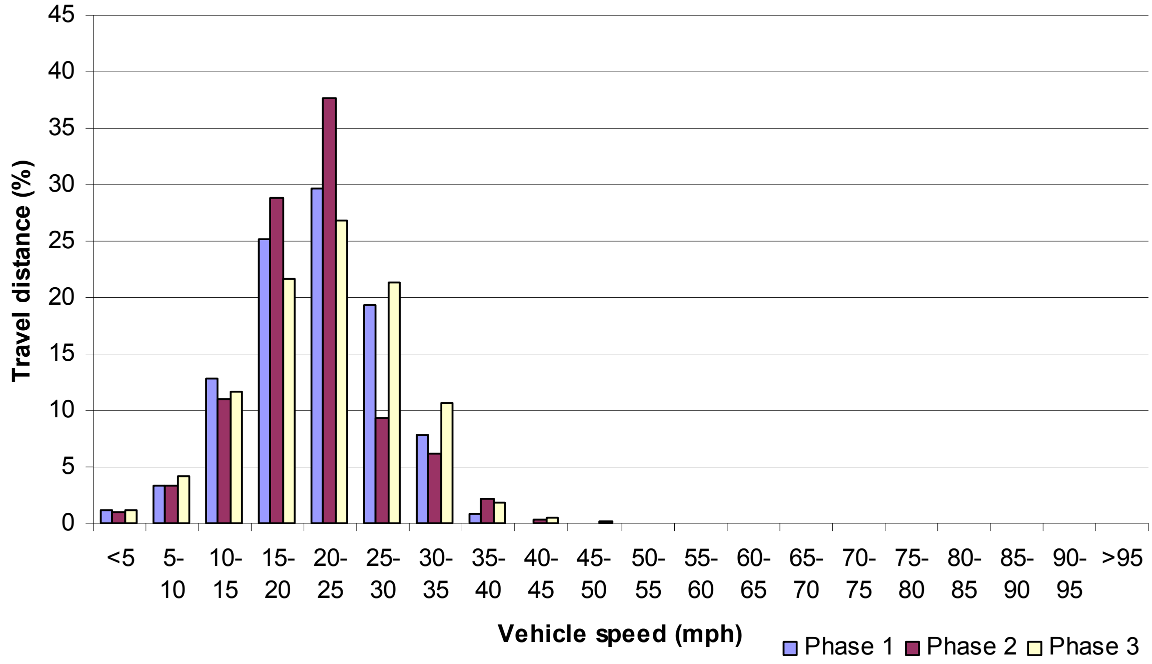
Coefficient of variation (CV) was also used to determine whether ISA led to more stable vehicle speed, as it has been suggested that CV of the speed distribution is related to accident occurrence (Taylor et al, 2000). CV is a dimensionless measure that allows comparison of the variation of populations having considerably different mean values, which is of particular use for this analysis since the speed zones range from 20 mph to 70 mph.

Figure 51 through Figure 56 illustrate speed distribution across speed zones from 20 mph to 70 mph respectively. Each figure consists of two graphs; the top graph shows speed distribution across trial phases, and the bottom graph shows speed distribution in Phase 2 only (i.e. when ISA was switched on), with a breakdown of system engaged (Opt-In) and system overridden (Opt-Out).

It is worth noting that participants seemed to have adapted their reference for their chosen speed between trial phases. During Phase 1 and 3 when the ISA system was turned off, many participants were observed to obey the speed limits with reference to the speedometer reading. During Phase 2, most participants were observed to rely on the ISA system (i.e. throttle feedback) instead of the speedometer reading.

The current design of the ISA system does not precisely restrict vehicle speed to posted speed limits (i.e. the speed limits provided by the digital speed limit map stored in the vehicle) all the time. Considering that trial participants may encounter a wide variety of road gradients, tolerance has been given to the throttle cut-off thresholds allowing the vehicle to be able to reach the speed limits on uphill roads. This design however leads to the vehicle being able to cross the speed limits on flat or downhill roads.

Since the participants treated the ISA system as cruise control and went for the maximum throttle allowance, slight distortion to the speed distribution when ISA was turned on was observed. This led to a slight drift of the speed distribution in Phase 2 around the legal speed limits, especially in lower speed zones. For example, in 20 mph zones (e.g. Figure 51), the peak of the speed distribution derived from Phase 2 was in the band of 20-25 mph rather than 15-20 mph. Nevertheless, the trial results undoubtedly demonstrate the effectiveness of the ISA system on reshaping speed distribution.



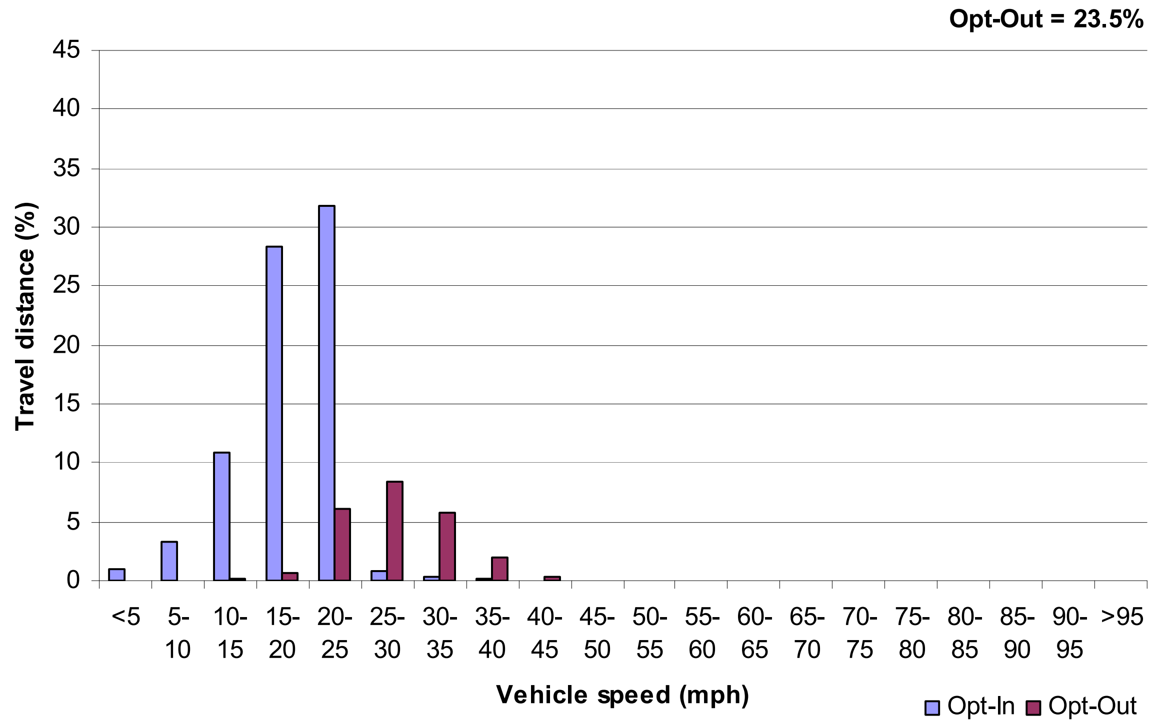
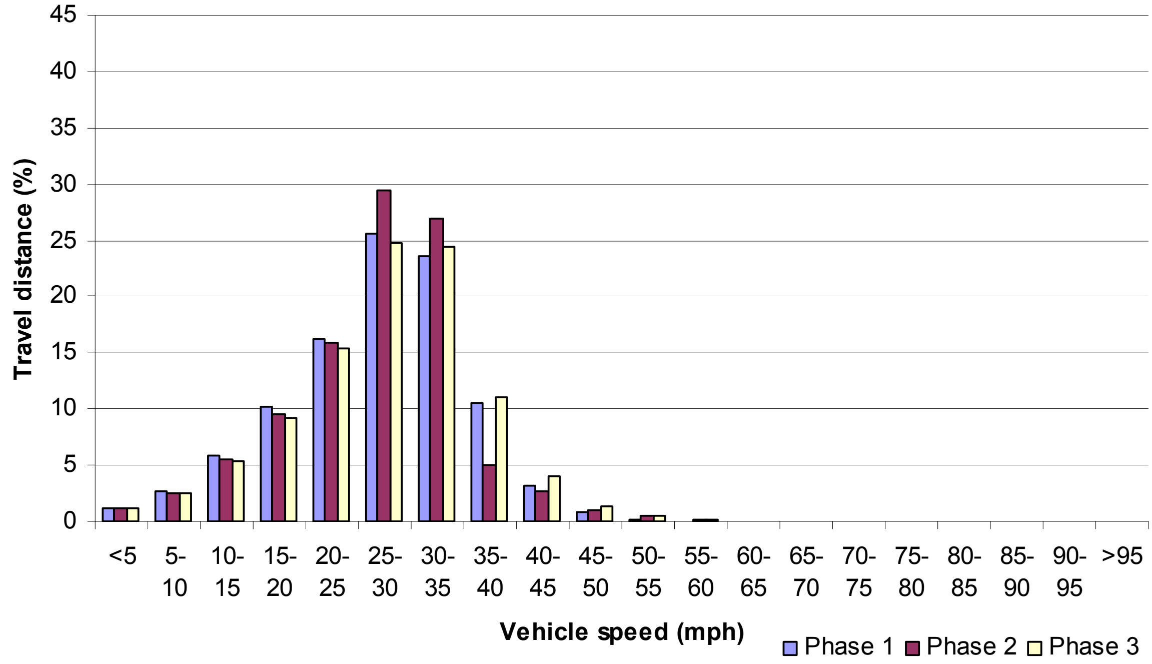


Figure 51: Overall speed distribution in 20 mph zones



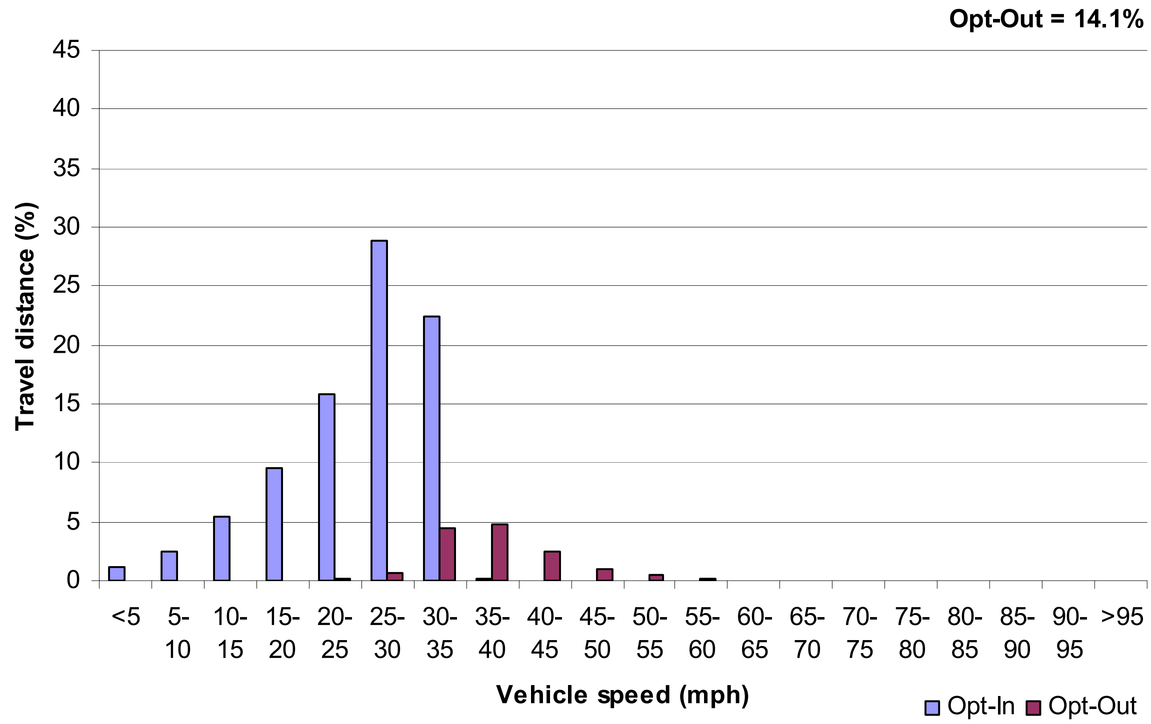
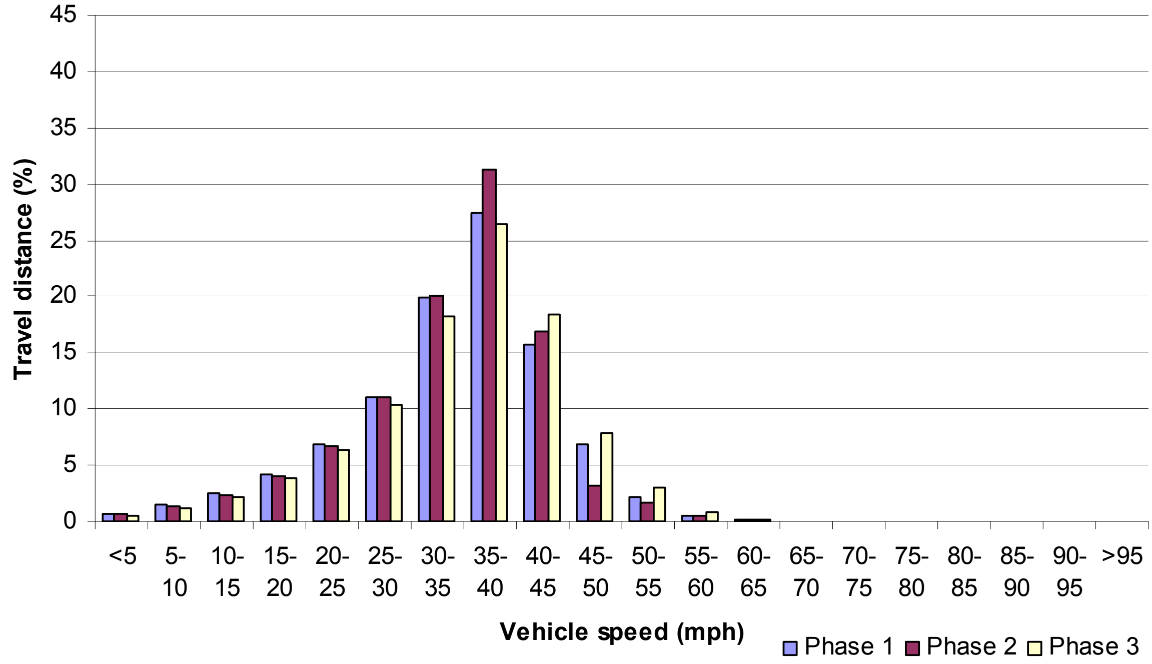


Figure 52: Overall speed distribution in 30 mph zones



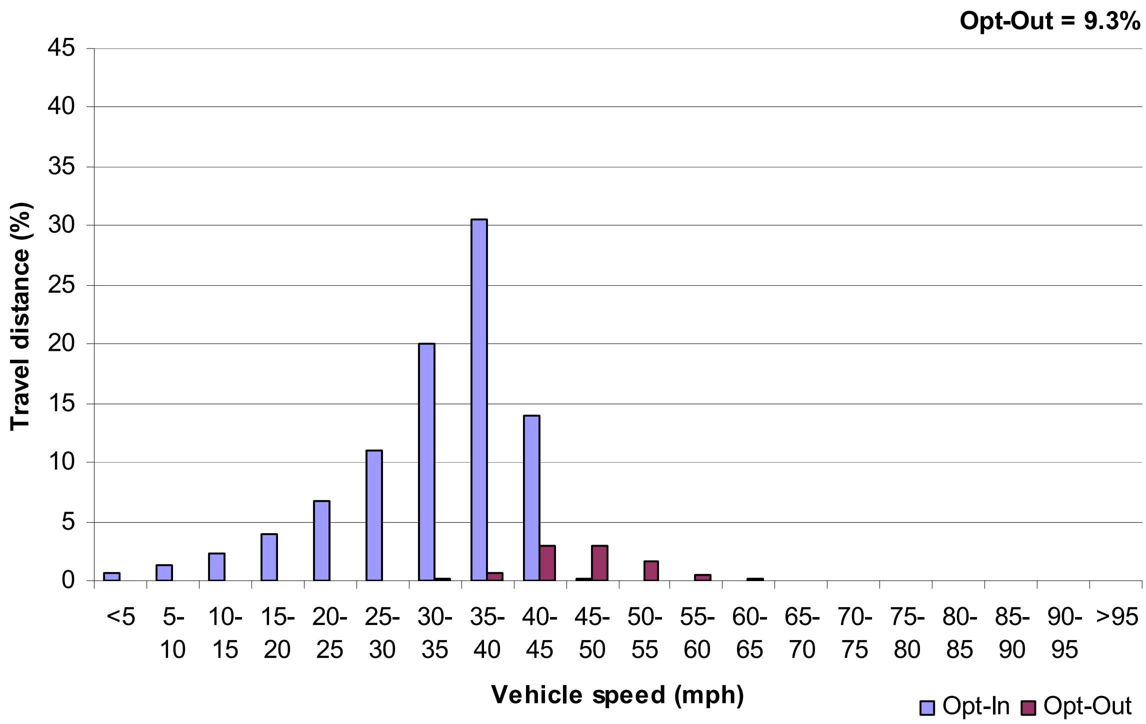
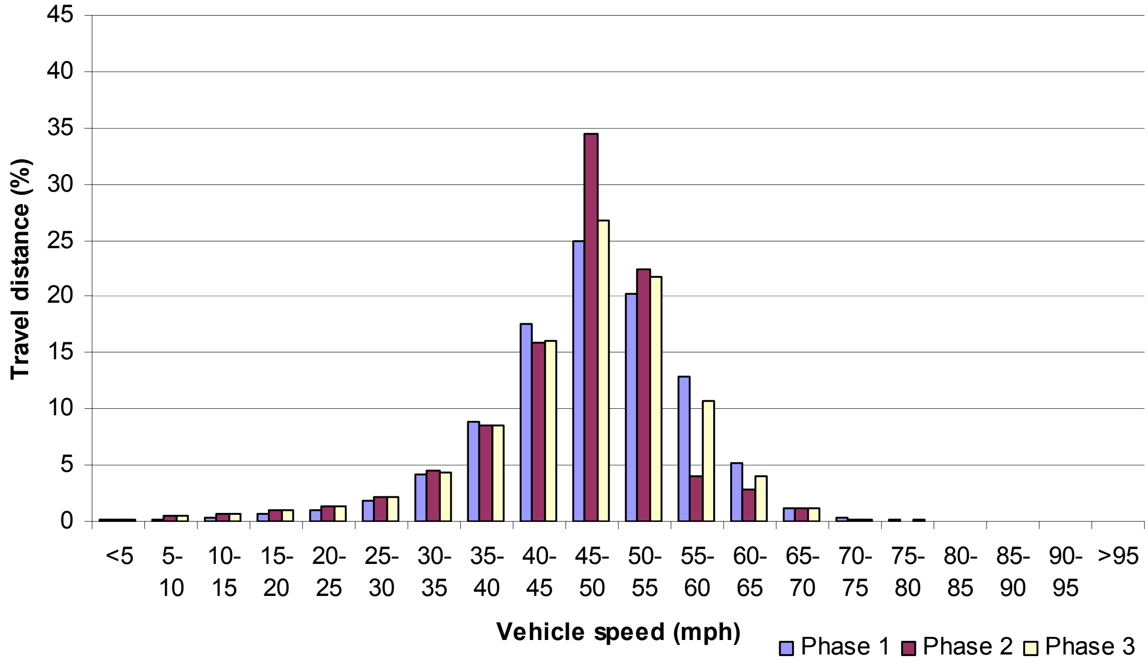


Figure 53: Overall speed distribution in 40 mph zones



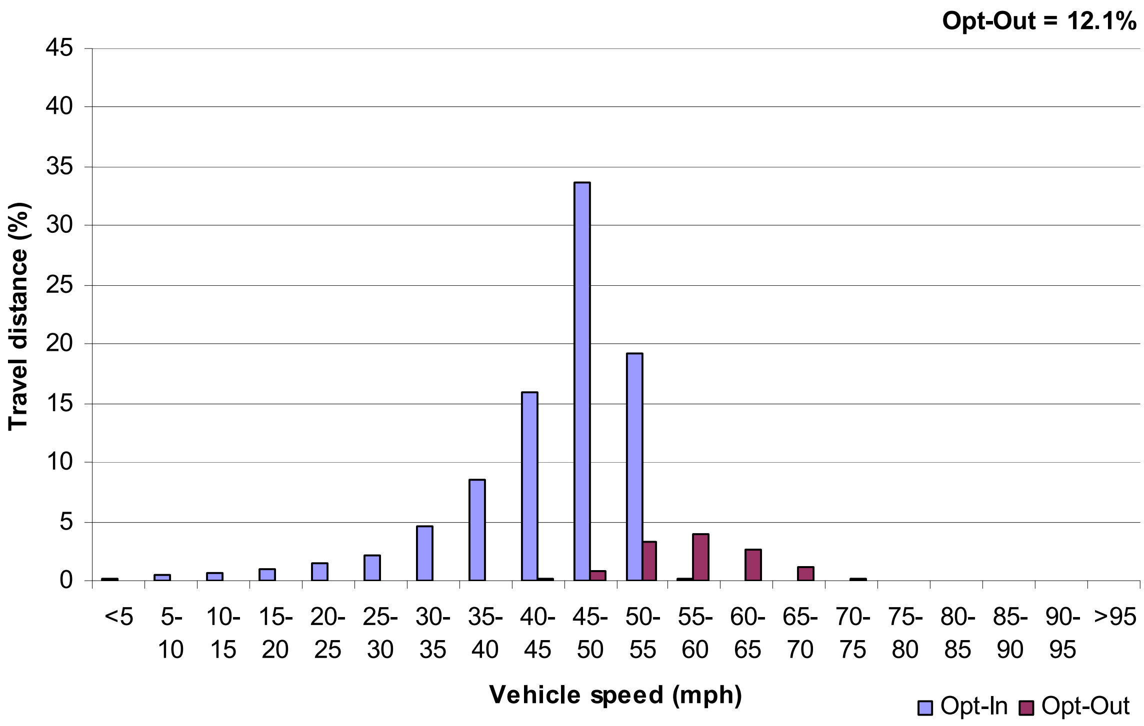
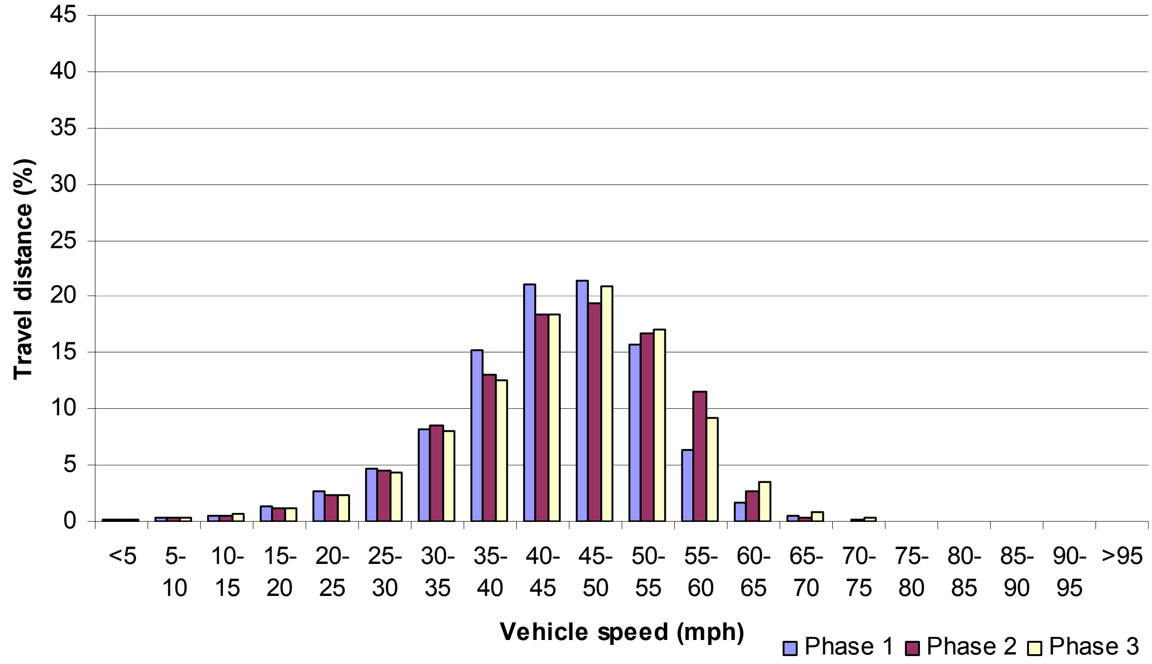


Figure 54: Overall speed distribution in 50 mph zones



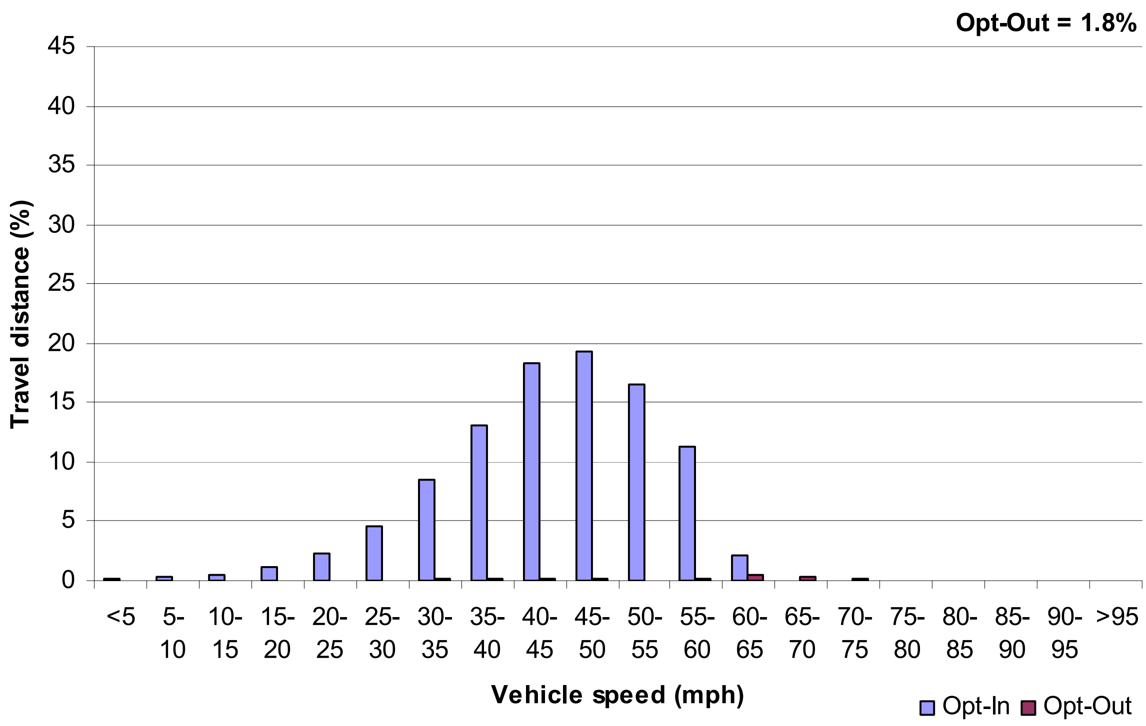
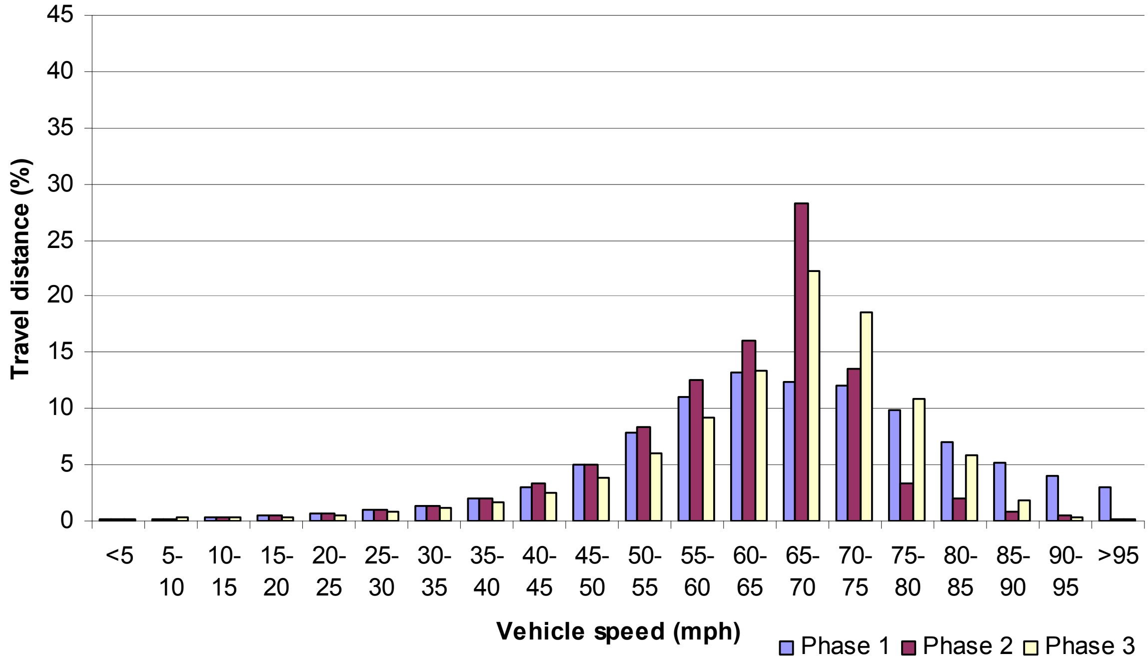


Figure 55: Overall speed distribution in 60 mph zones



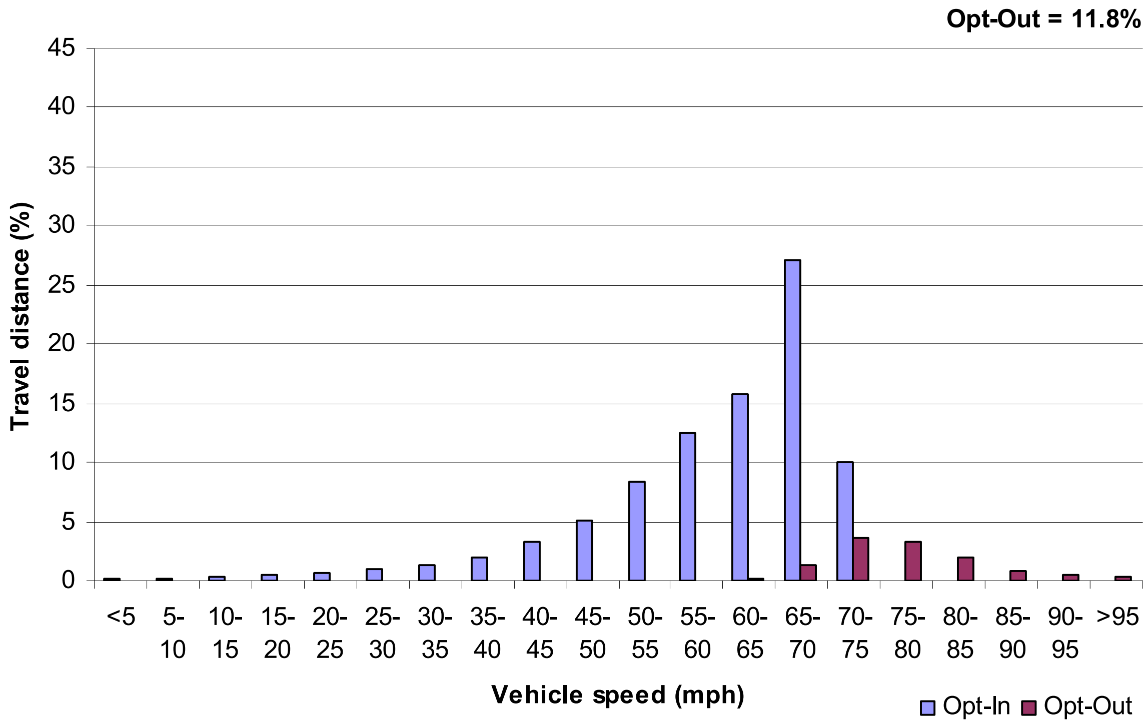


Figure 56: Overall speed distribution in 70 mph zones

The effect of ISA intervention on the shape of the speed distribution is prominent across speed zones, except for the 60 mph zones, in which speeding behaviour had rarely been recorded when ISA was not available. This is considered to be primarily due to the constrains on driving speed imposed by road geometry, as the 60 mph speed limit is applicable to most rural roads where the layout is usually single carriageway.

The speed distribution derived from Phase 1 in the 70 mph zones shows a very different shape from the speed distribution derived from Phase 3, although both phases refer to ISA switched off. This was attributable to a participant (young male, intender) who showed distinct travel characteristics across trial phases, as depicted in Table 25.

This participant clearly travelled at excessively high speeds. The influence of his speed choice to the overall speed distribution was further magnified by his travel distance. As shown in Table 25, his contribution to the total travel distance in Phase 1 was exceptionally high. It is worth mentioning that Phase 2 spread over a 4-month period while Phase 1 and 3 only covered one month duration respectively, but his travel distance in Phase 1 was more than Phase 2. During Phase 3, his contribution to the total travel distance was far diminished, in addition to an apparent rectification in his speeding behaviour.

The changes in this participant's choice of speed across trial phases might not be entirely attributable to ISA intervention, as his travel distance significantly varied across phases as well. It is worth noting that this participant was caught for speeding by a speed camera about two weeks before he was switched to Phase 3, which might have partially contributed to his choice of speed and exposure to the driving environment during Phase 3.

Table 25: Travel characteristics of Participant 21 in the 70 mph zones

	Phase 1	Phase 2	Phase 3
Mean speed (mph)	82.7	74.6	69.4
The 85th percentile of the speed distribution (mph)	94.6	89.4	70.6
Max speed (mph)	112.35	105.03	78.96
Travel distance (km)	1159	1024	26
Contribution to total travel distance	22%	5%	0.4%

Apart from the 70 and the 60 mph zones, those figures referring to the remaining four speed zones reveal that the shapes of the speed distribution from Phase 1 and Phase 3 were generally very similar. This suggests that ISA effectively changed the speed distribution but that the carry-over effect was minimal.

Moreover, in speed zones where a substantial portion of the speed distribution was over the posted speed limits during Phase 1 and 3, considerable ISA overriding was also observed during Phase 2. This suggests that drivers who used to speed might find it difficult to refrain from speeding at the presence of an overridable ISA system. This phenomenon clearly highlights the value of introducing a mandatory ISA system over advisory ISA system in order to reinforce compliance with speed limits. Although an overridable ISA system may be considered to be useful under certain circumstances (e.g. overtaking a show moving lorry), its effect on transforming speed distribution and therefore enhancing road safety could be compromised by excessive overriding.

Figure 57 compares the observed overriding behaviour within in speed zones, which highlights concerns over the influence of ISA intervention on diminishing speed behaviour due to the system being overridden, especially on urban roads (i.e. 20, 30, and 40 mph zones) where drivers are most likely to encounter vulnerable road users such as pedestrians and cyclists.

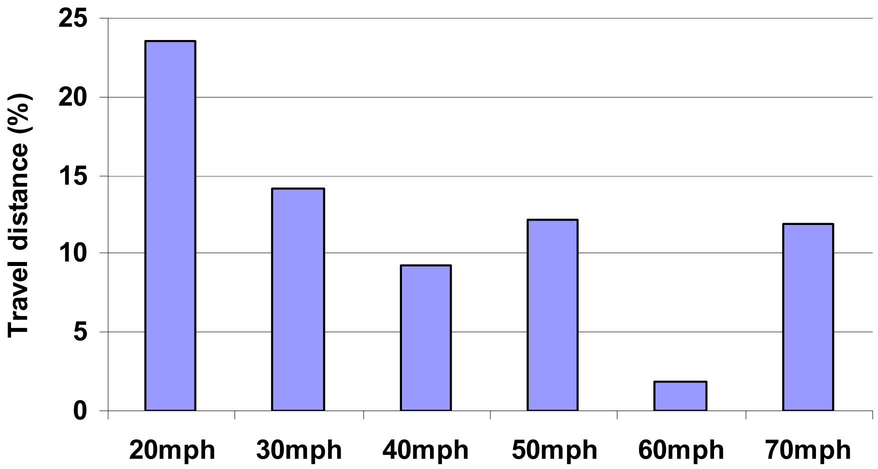


Figure 57: Comparison of overriding behaviour within individual speed zones

Figure 58 illustrates the distribution of overriding behaviour across speed zones based on the total travel distance when the ISA system was overridden, and clearly demonstrates that ISA was most likely to be overridden in the urban environment, where it could be argued that on safety grounds it was needed most.

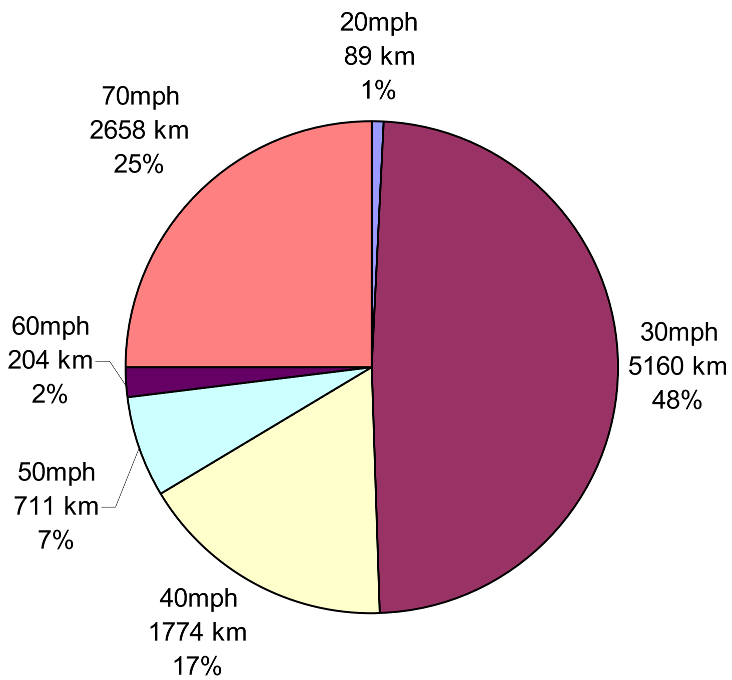


Figure 58: Distribution of travel distance with ISA overridden

The data were also integrated on the basis of individual participants with respect to trial phases and speed zones allowing repeated measures ANOVA's to be carried out against key statistics of the speed distribution in each speed zone across trial phases. Statistics tests were carried out against central tendency of the distribution via the mean, the median, and the mode, and against the skewness of the distribution towards the right end via the 85th, the 90th, and the 95th percentile. Given that the ANOVA results and the trend of changes across trial phases were very similar for the three statistics indicating central tendency and across the three high percentiles, one measure was chosen to reflect each. Due to the importance of the mean and the 85th percentile of the speed distribution to research into subjective choice of speed, only these two statistics are presented and discussed as follows.

Comparison of these two key statistics (Figure 59) across trial phases in each speed zone, illustrates that ISA consistently reduced the mean and the 85th percentile of the speed distribution across speed zones (i.e. a 'V' shape, the statistic in question goes down from Phase 1 to Phase 2, then rises again from Phase 2 to Phase3). A few exceptions are noted (i.e. the 60 mph zones across the two graphs and the 70 mph zones in the top graph) which are considered to be primarily attributable to the behavioural changes in participants' reference for their chosen speed between trial phases, as mentioned in the beginning of this section.

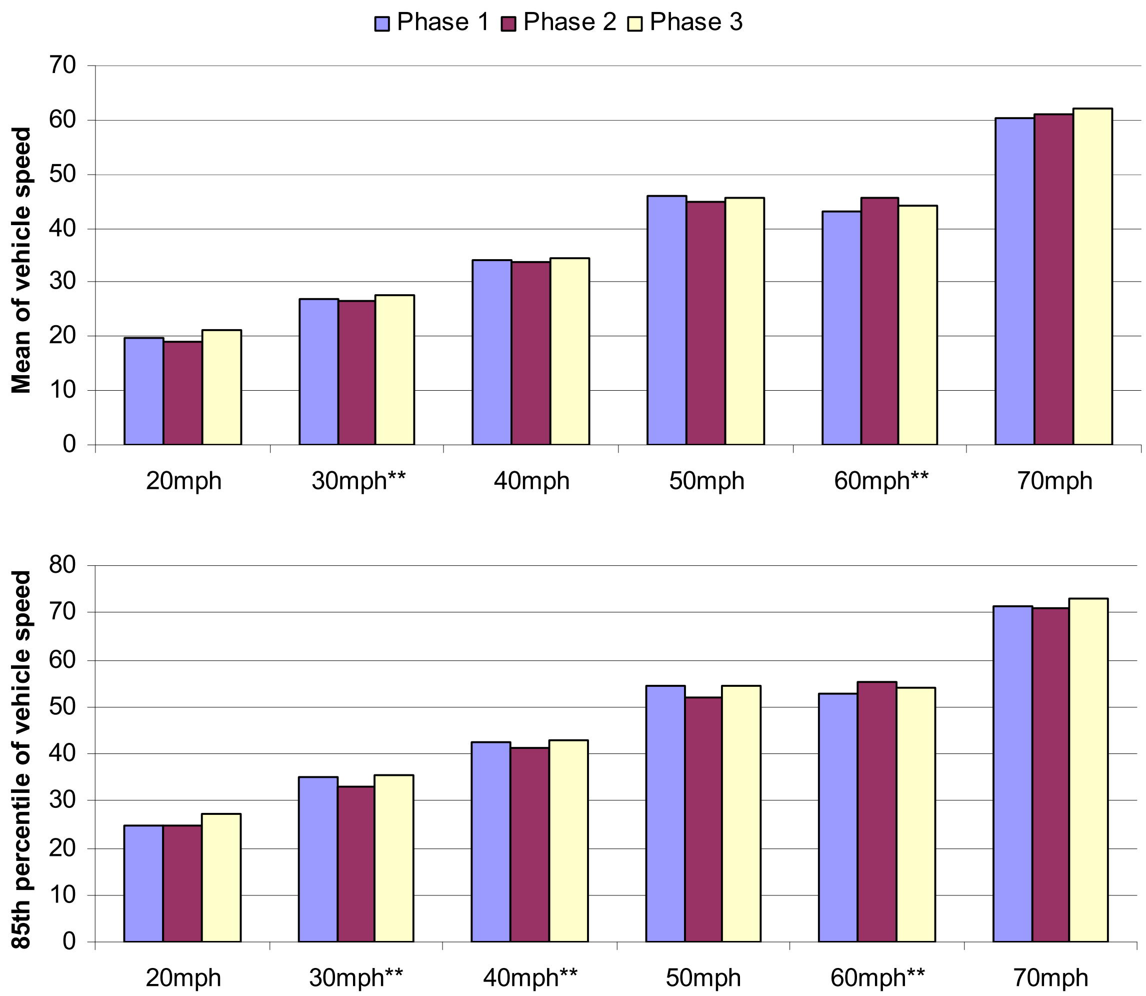


Figure 59: Comparison of key statistics of the speed distribution across trial phases

Table 26 presents the test results of a series of repeated measures ANOVAs, which confirm that ISA effectively changed the speed distribution, especially in urban areas where lower speed limits normally apply. It is worth noting that the significance of the ANOVA test results largely depends on sample size. For example, the difference in mean speed in the 20 and the 40 mph zones was nearly significant, which implies that, when the sample size increases (i.e. more vehicles on the road are equipped with ISA); it is very likely that the difference would become significant. In addition, the data used for the ANOVA include the travel distance when ISA was overridden in Phase 2, which suggests that the effectiveness of ISA intervention in diminishing speeding behaviour has not been traded off by the system being overridable. This undoubtedly boosts the confidence in suggesting that a mandatory ISA system will further diminish speeding behaviour.

Table 26: Results of ANOVA for key statistics of the speed distribution

<table>
<tr><th rowspan="2">Statistic</th><th rowspan="2">Speed zone</th><th rowspan="2">Phase 1</th><th rowspan="2">Phase 2</th><th rowspan="2">Phase 3</th><th colspan="3">Repeated measures ANOVA</th><th colspan="3" rowspan="2">Post-hoc t-tests</th></tr>
<tr><th>F statistic</th><th>significance</th><th>Effect size</th></tr>
<tr><td rowspan="18">Mean speed</td><td rowspan="3">20</td><td rowspan="3">19.61</td><td rowspan="3">19.20</td><td rowspan="3">21.15</td><td rowspan="3">F(2,22) = 2.91</td><td rowspan="3">0.076</td><td rowspan="3">0.209</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>×</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>*</td></tr>
<tr><td rowspan="3">30</td><td rowspan="3">26.94</td><td rowspan="3">26.41</td><td rowspan="3">27.52</td><td rowspan="3">F(2,36) = 11.26</td><td rowspan="3">< 0.0005**</td><td rowspan="3">0.385</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>*</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>*</td></tr>
<tr><td rowspan="3">40</td><td rowspan="3">34.03</td><td rowspan="3">33.70</td><td rowspan="3">34.52</td><td rowspan="3">F(2,36) = 3.14</td><td rowspan="3">0.055</td><td rowspan="3">0.149</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>×</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>*</td></tr>
<tr><td rowspan="3">50</td><td rowspan="3">46.02</td><td rowspan="3">44.89</td><td rowspan="3">45.59</td><td rowspan="3">F(2,34) = 0.86</td><td rowspan="3">0.430</td><td rowspan="3">0.048</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>×</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>×</td></tr>
<tr><td rowspan="3">60</td><td rowspan="3">43.00</td><td rowspan="3">45.48</td><td rowspan="3">44.02</td><td rowspan="3">F(2,36) = 7.31</td><td rowspan="3">0.002**</td><td rowspan="3">0.289</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>**</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>×</td></tr>
<tr><td rowspan="3">70</td><td rowspan="3">60.16</td><td rowspan="3">61.06</td><td rowspan="3">62.14</td><td rowspan="3">F(2,36) = 0.62</td><td rowspan="3">0.545</td><td rowspan="3">0.033</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>×</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>×</td></tr>
<tr><td rowspan="18">85th percentile</td><td rowspan="3">20</td><td rowspan="3">24.90</td><td rowspan="3">24.84</td><td rowspan="3">27.40</td><td rowspan="3">F(2,22) = 2.45</td><td rowspan="3">0.109</td><td rowspan="3">0.182</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>×</td><td>*</td></tr>
<tr><td>PH2</td><td></td><td>×</td></tr>
<tr><td rowspan="3">30</td><td rowspan="3">34.95</td><td rowspan="3">32.99</td><td rowspan="3">35.58</td><td rowspan="3">F(2,36) = 28.86</td><td rowspan="3">< 0.0005**</td><td rowspan="3">0.616</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>**</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>**</td></tr>
<tr><td rowspan="3">40</td><td rowspan="3">42.50</td><td rowspan="3">41.30</td><td rowspan="3">42.96</td><td rowspan="3">F(2,36) = 5.82</td><td rowspan="3">0.006**</td><td rowspan="3">0.244</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>*</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>**</td></tr>
<tr><td rowspan="3">50</td><td rowspan="3">54.24</td><td rowspan="3">52.08</td><td rowspan="3">54.29</td><td rowspan="3">F(2,34) = 1.40</td><td rowspan="3">0.259</td><td rowspan="3">0.076</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>×</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>×</td></tr>
<tr><td rowspan="3">60</td><td rowspan="3">52.99</td><td rowspan="3">55.44</td><td rowspan="3">54.05</td><td rowspan="3">F(2,36) = 5.52</td><td rowspan="3">0.008**</td><td rowspan="3">0.235</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>**</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>×</td></tr>
<tr><td rowspan="3">70</td><td rowspan="3">71.45</td><td rowspan="3">70.98</td><td rowspan="3">73.00</td><td rowspan="3">F(2,36) = 0.62</td><td rowspan="3">0.546</td><td rowspan="3">0.033</td><td></td><td>PH2</td><td>PH3</td></tr>
<tr><td>PH1</td><td>×</td><td>×</td></tr>
<tr><td>PH2</td><td></td><td>×</td></tr>
</table>

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant

Table 27 presents the coefficient of variation (CV) derived from individual trial phases as well as speed zones, which indicates the effect of ISA on the stability of vehicle speed. ISA led to a reduction in CV in most speed zones, as the CV derived from Phase 2 was generally smaller than that from Phase 1 or 3, apart from the difference between Phase 1 and 2 in the 50 and the 60 mph zones. At the overall level, the effect of ISA on a reduction in CV is prominent. As discussed in the beginning of this section, a reduction in CV would lead to deceased accident occurrence, which highlights the benefit of ISA to accident reduction.

Table 27: Coefficient of variation of vehicle speed across trial phases

Speed zone	Phase 1	Phase 2	Phase 3
20 mph	0.307	0.306	0.328
30 mph	0.315	0.302	0.318
40 mph	0.282	0.265	0.277
50 mph	0.200	0.201	0.217
60 mph	0.228	0.235	0.239
70 mph	0.248	0.203	0.203
Overall	0.479	0.428	0.441

5.5 Analysis of vehicle speed by demographic groups

This section presents analysis of the speed distribution in terms of participants' demographic characteristics: gender, age, and intention to speed. The initial grouping by attitudes did not provide homogeneous behaviour. A decision was therefore made to regroup participants into 'intenders' and 'non-intenders' based on participants' intention to break speed limits by the intention scores reported in Section 4.2. This classification was regarded as more reliable than the original grouping method which was based on driver attitude towards a system with which they had no experience. This intention grouping will be applicable to all future analyses. The number of participants in each demographic group used in the analysis presented in this section is specified in Table 28.

Table 28: Number of participants by demographic categories

	Male		Female		Total
	Intender	Non-Intender	Intender	Non-Intender	
Young	2	3	2	3	10
Old	2	3	2	3	10
Total	4	6	4	6	20

5.5.1 Gender

Table 29 depicts a breakdown of vehicle kilometres across trial phases, speed zones and participants' gender groups, which shows that female participants contributed a slightly longer travel distance than male participants. Figure 60 further compares the distribution of travel distance between the two gender groups. Although there is no distinct within-group difference (i.e. male participants drove most frequently in 30 mph zones, followed by 70 mph zones, then 40 mph zones across trial phases, while female participants drove most frequently in 30 mph zones, followed by 40 mph zones, then 70 mph zones), it reveals that female participants drove in urban environments relatively more often than male participants.

Table 29: Vehicle kilometres across trial phases, speed zones and gender groups

Speed zone	Male			Female		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
20 mph	102	260	60	21	120	45
30 mph	5,366	18,570	4,955	4,828	18,047	5,015
40 mph	2,296	7,857	2,361	2,777	11,217	2,995
50 mph	412	3,016	776	740	2,827	855
60 mph	855	3,738	1,211	1,303	7,600	1,525
70 mph	3,787	11,599	5,035	1,495	10,853	2,177
Sum	72,255			74,441		

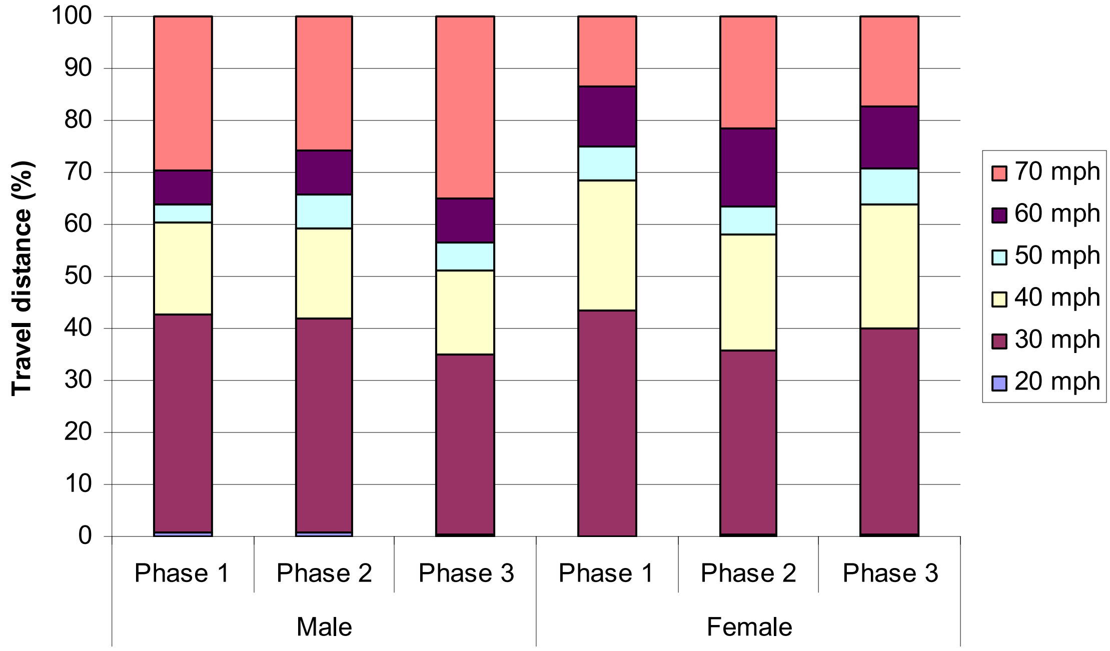


Figure 60: Comparison of patterns of travel distance between gender groups

Figure 61 through Figure 66 compare speed distribution across trial phases between the two gender groups. ISA effectively reshaped the speed distribution for both groups across speed zones but male participants were observed to have overridden the system more frequently than female participants across most of the speed zones.

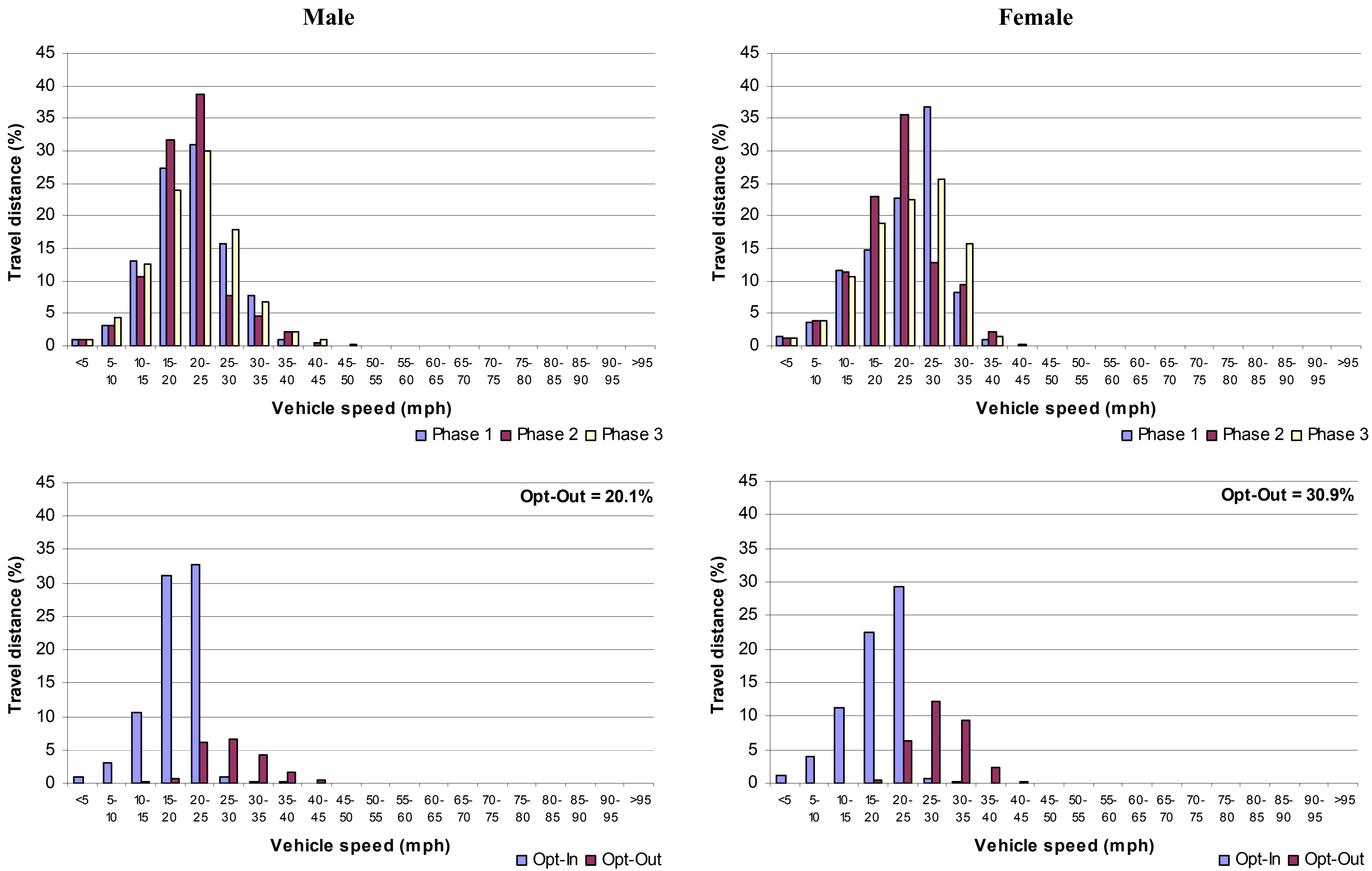


Figure 61: Comparison of the speed distribution in 20 mph zones by gender

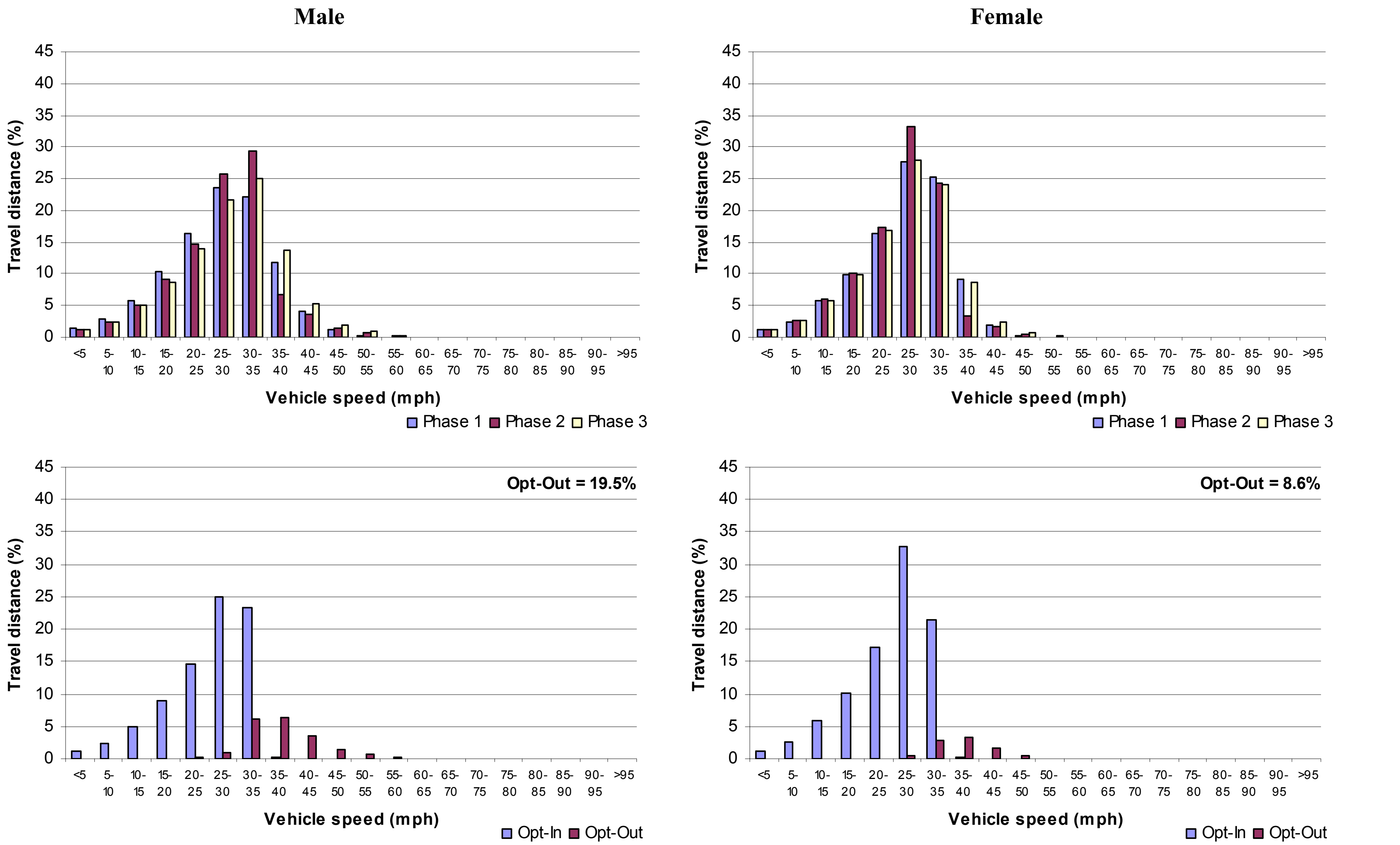


Figure 62: Comparison of the speed distribution in 30 mph zones by gender

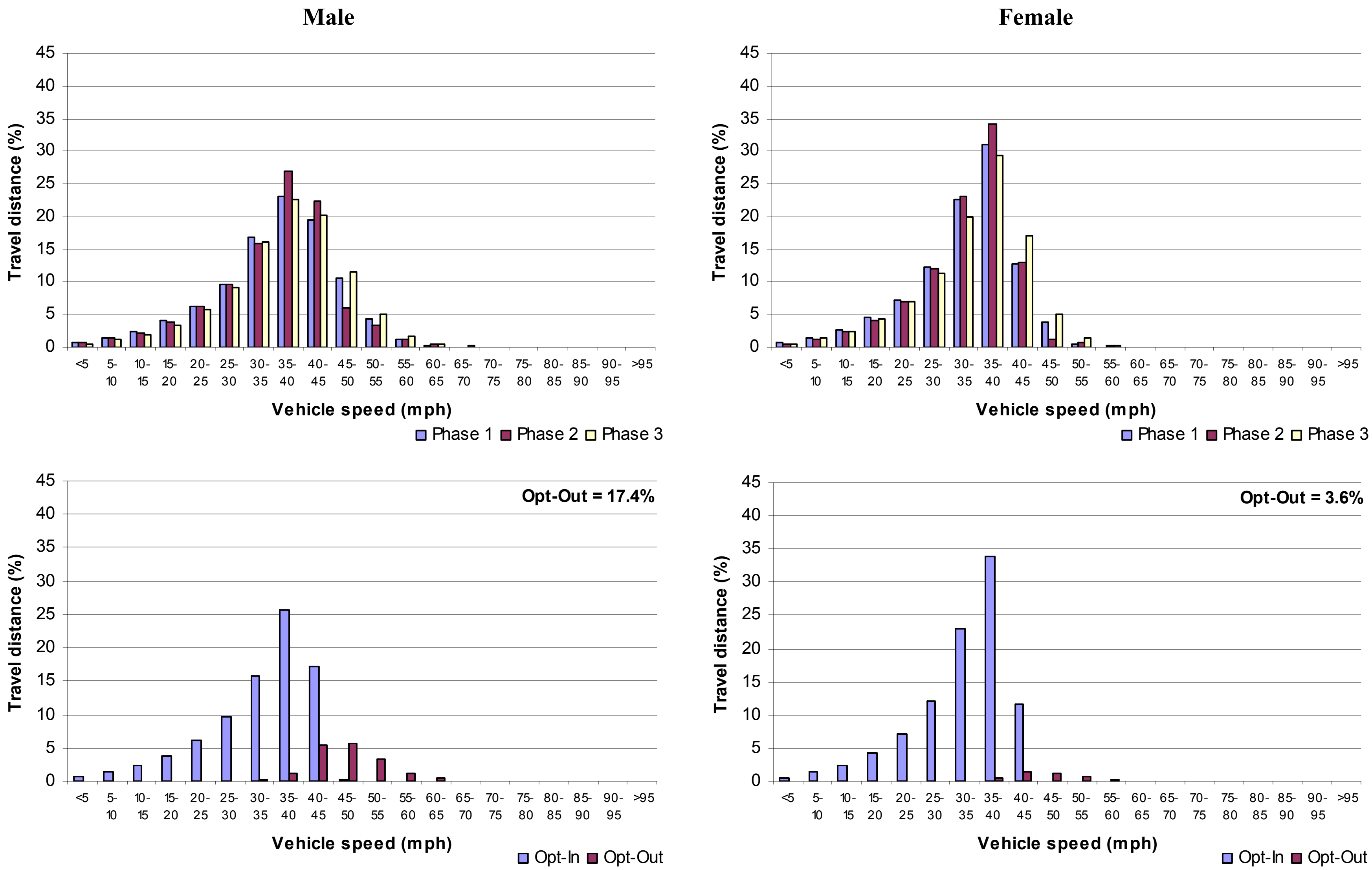


Figure 63: Comparison of the speed distribution in 40 mph zones by gender

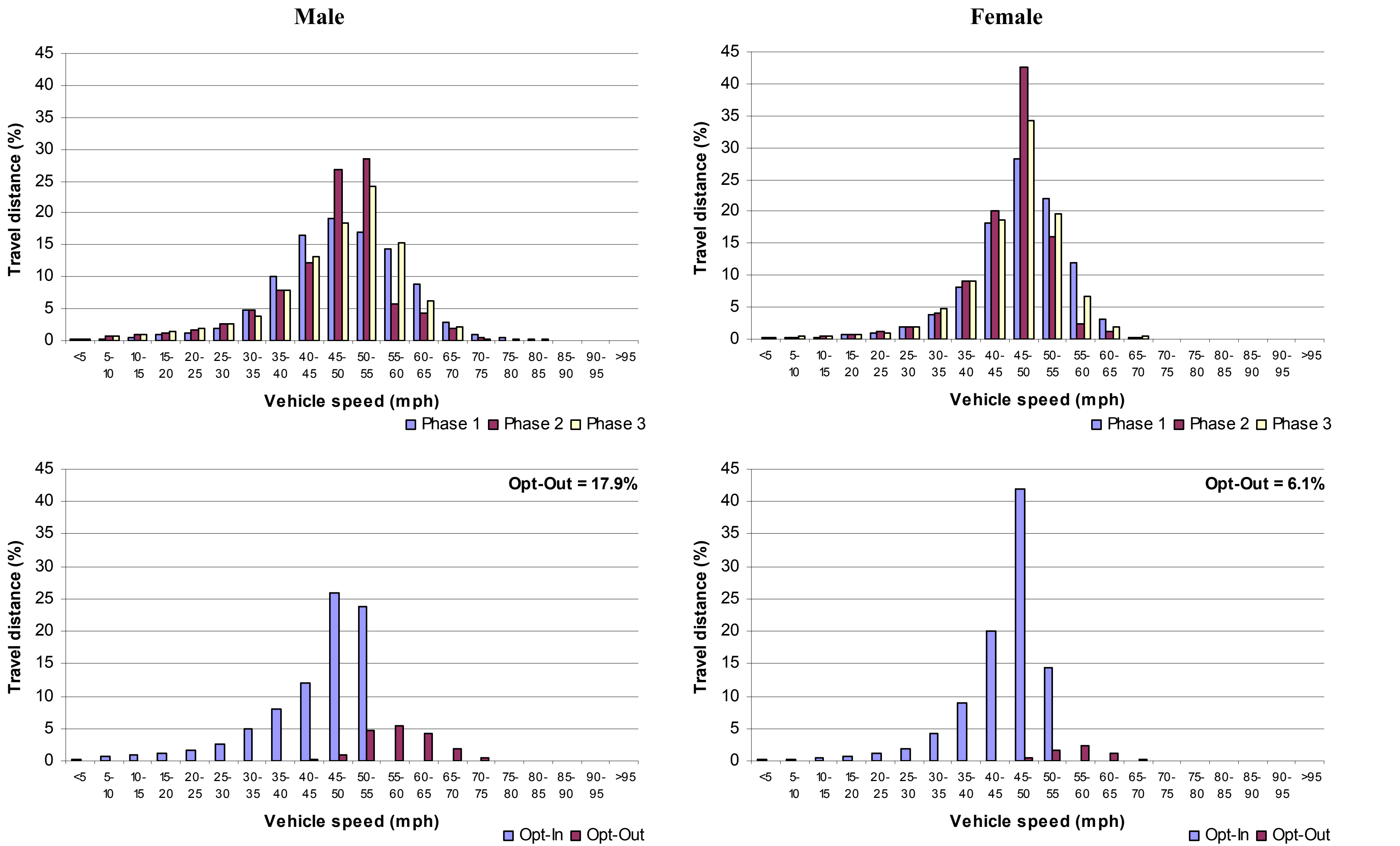


Figure 64: Comparison of the speed distribution in 50 mph zones by gender

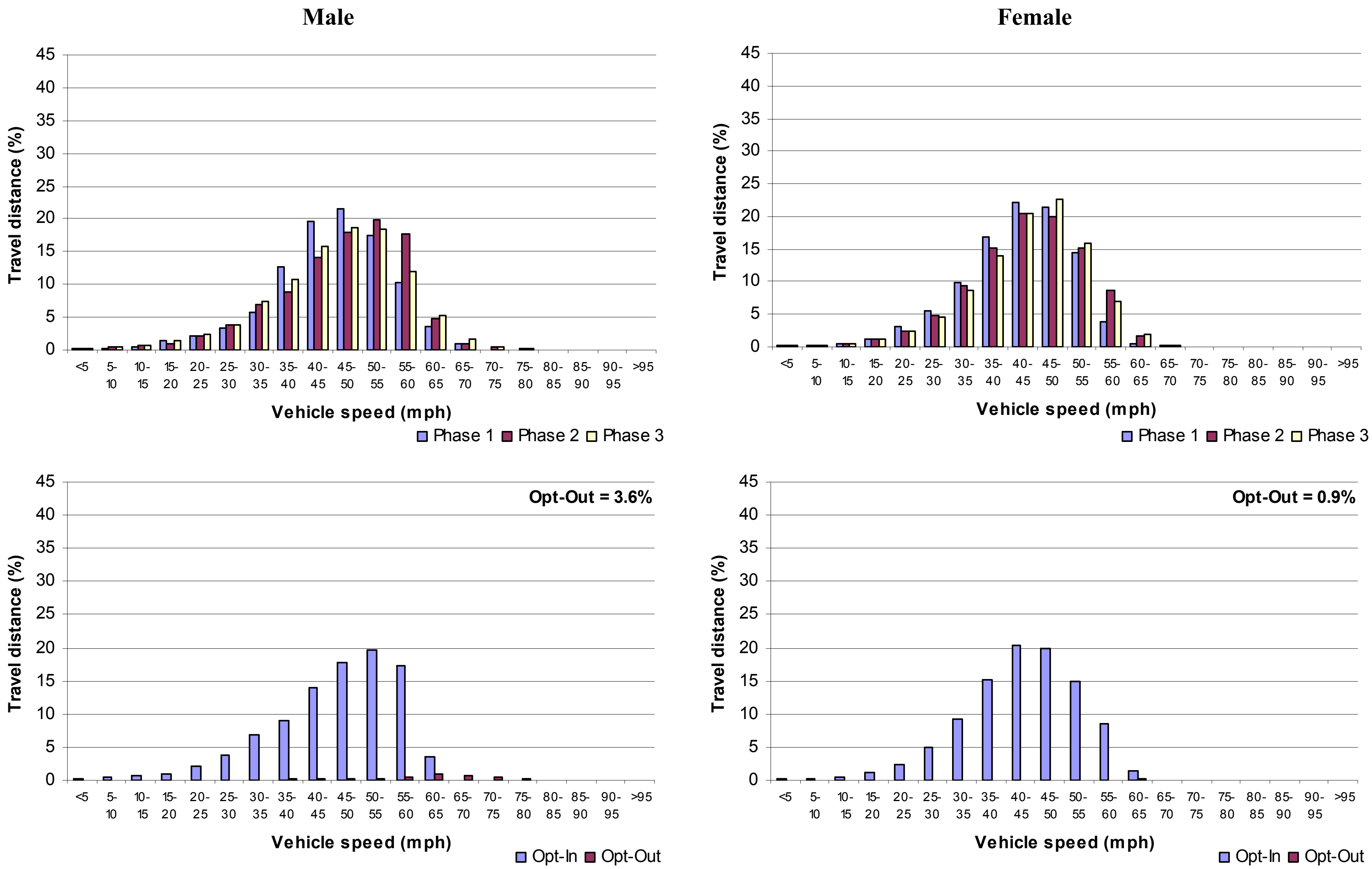


Figure 65: Comparison of the speed distribution in 60 mph zones by gender

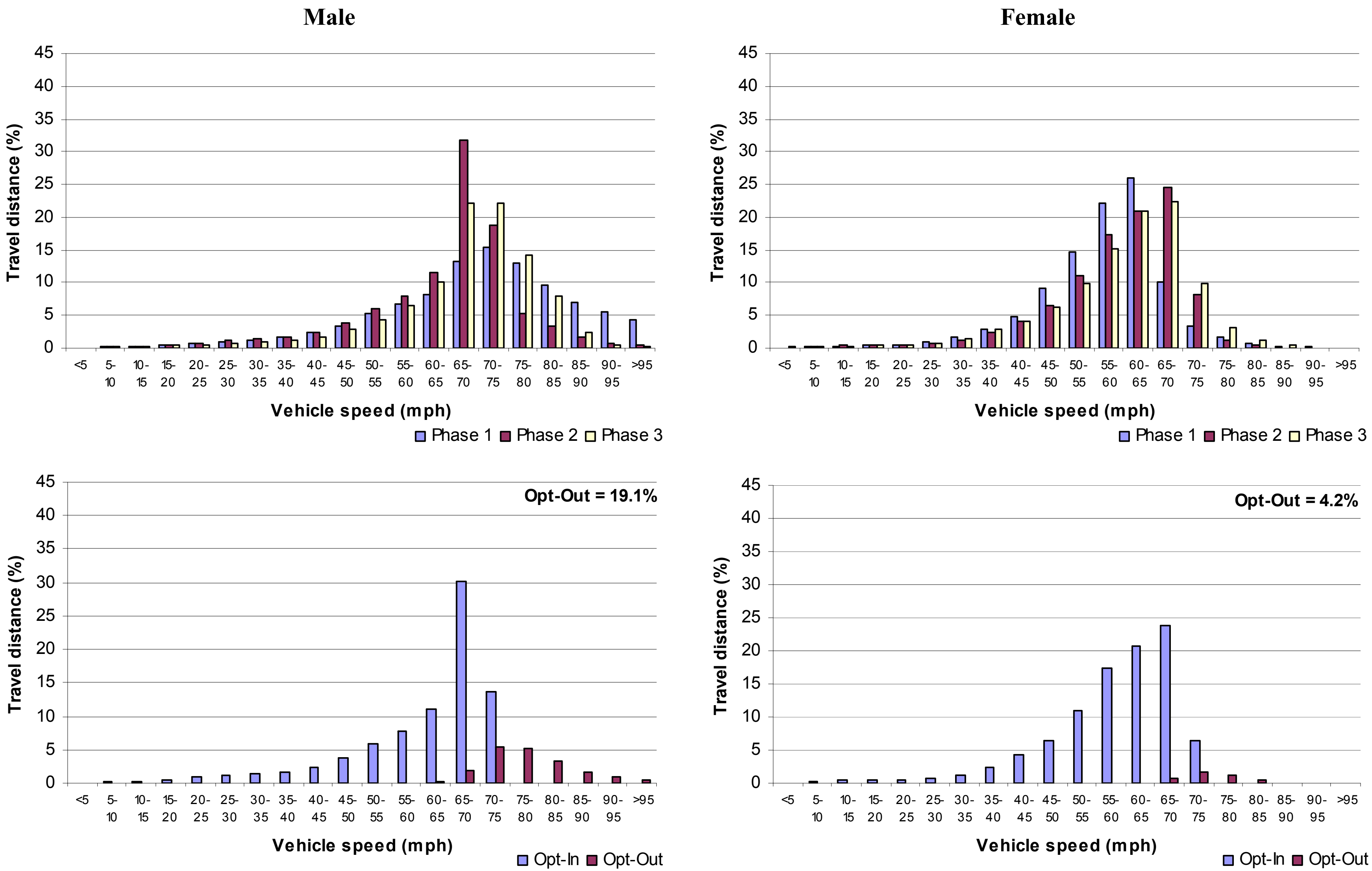


Figure 66: Comparison of the speed distribution in 70 mph zones by gender

Figure 67 compares the mean and the 85th percentile across trial phases in each speed zone between the two gender groups. Results were similar to those observed previously in that ISA led to a 'V' shape across speed zones and gender groups, with only a few exceptions. As explained earlier, the slight distortion was presumably attributable to differences in participants' reference for choice of speed across trial phases. In addition, male participants generally demonstrated a higher mean and 85th percentile across speed zones than female participants.

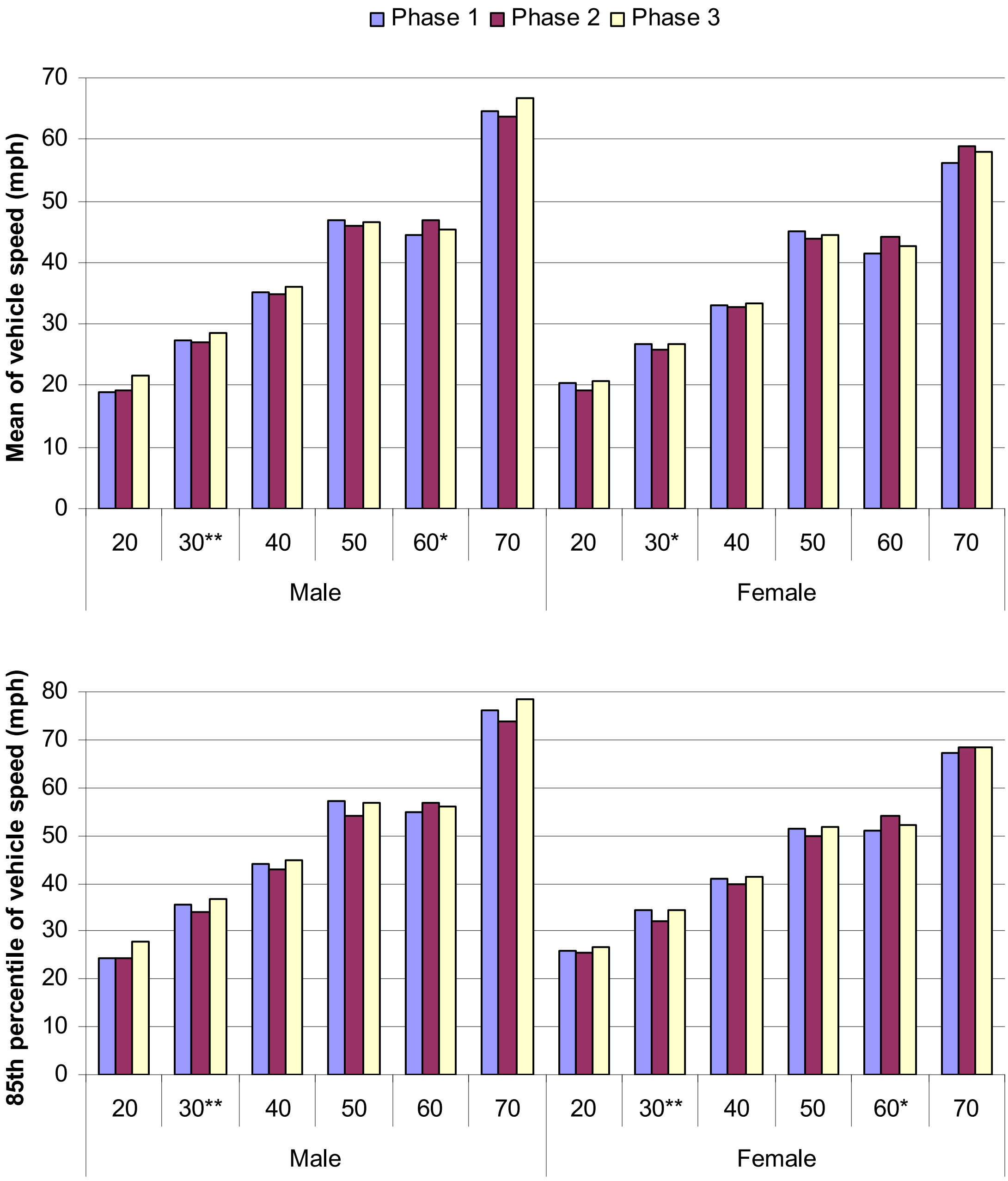


Figure 67: Comparison of key statistics of the speed distribution across trial phases by gender

A series of repeated measures ANOVAs were carried out to confirm the difference across trial phases in individual speed zones; significant results are annotated in Figure 67 but detailed test results are given in Appendix D. As shown in Figure 67, both groups demonstrated similar patterns with respect to the ANOVA results.

5.5.2 Age

Table 30 depicts a breakdown of vehicle kilometres across trial phases, speed zones and participants' age groups, and shows that older participants contributed longer travel distance than younger participants. Figure 68 further compares the distribution of travel distance between the two groups. There is neither distinct within-group nor between-group differences. Both groups of participants drove most frequently in 30 mph zones, followed by 70 mph zones, then 40 mph zones across trial phase.

Table 30: Vehicle kilometres across trial phases, speed zones and age groups

Speed zone	Young			Old		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
20 mph	37	154	48	85	227	56
30 mph	4,488	18,461	4,737	5,706	18,157	5,232
40 mph	2,100	9,174	2,600	2,974	9,900	2,756
50 mph	748	3,856	939	405	1,988	692
60 mph	733	4,476	1,117	1,425	6,863	1,619
70 mph	2,680	9,953	3,520	2,602	12,498	3,692
Sum	69,820			76,876		

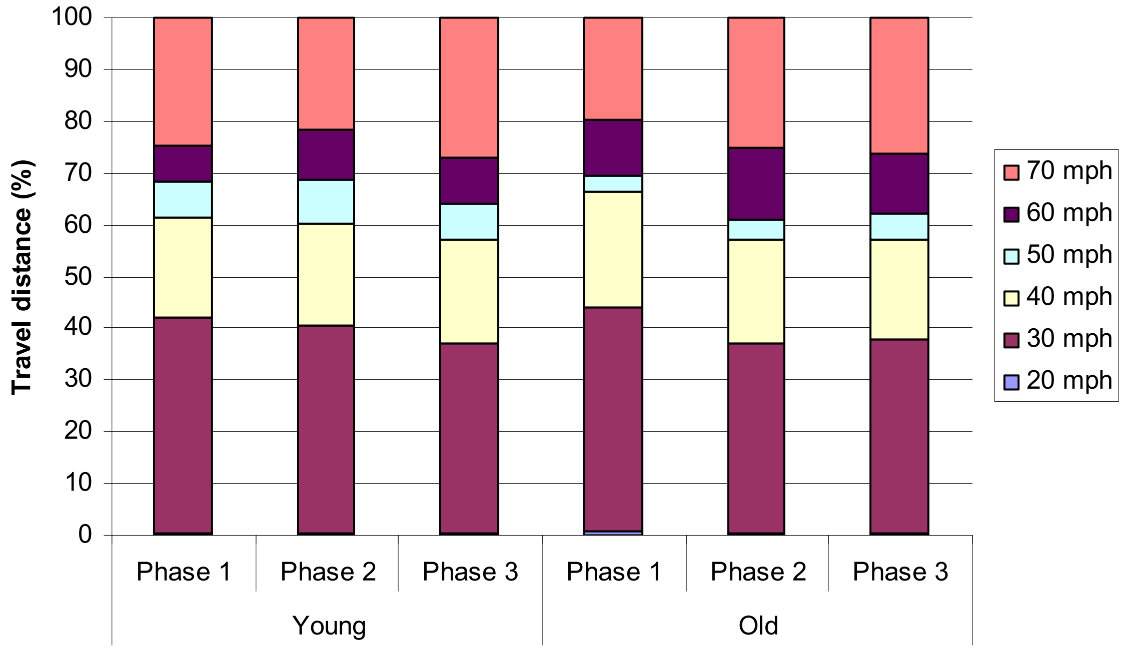


Figure 68: Comparison of patterns of travel distance between age groups

Figure 69 through Figure 74 compare speed distribution across trial phases between the two age groups. ISA effectively reshaped the speed distribution for both groups across speed zones but younger participants were observed to have overridden the system more frequently than older participants across most of the speed zones.

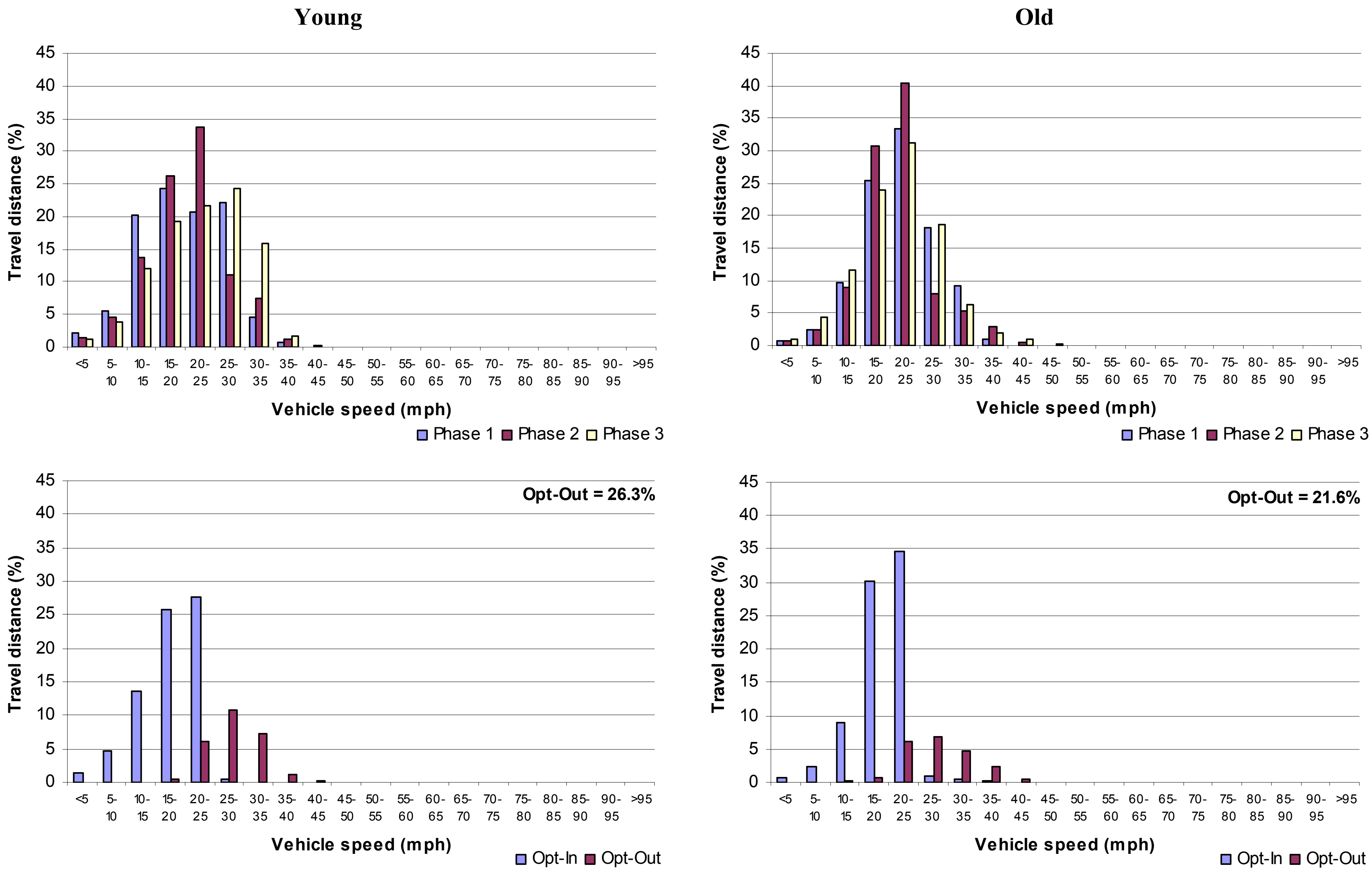


Figure 69: Comparison of the speed distribution in 20 mph zones between age groups

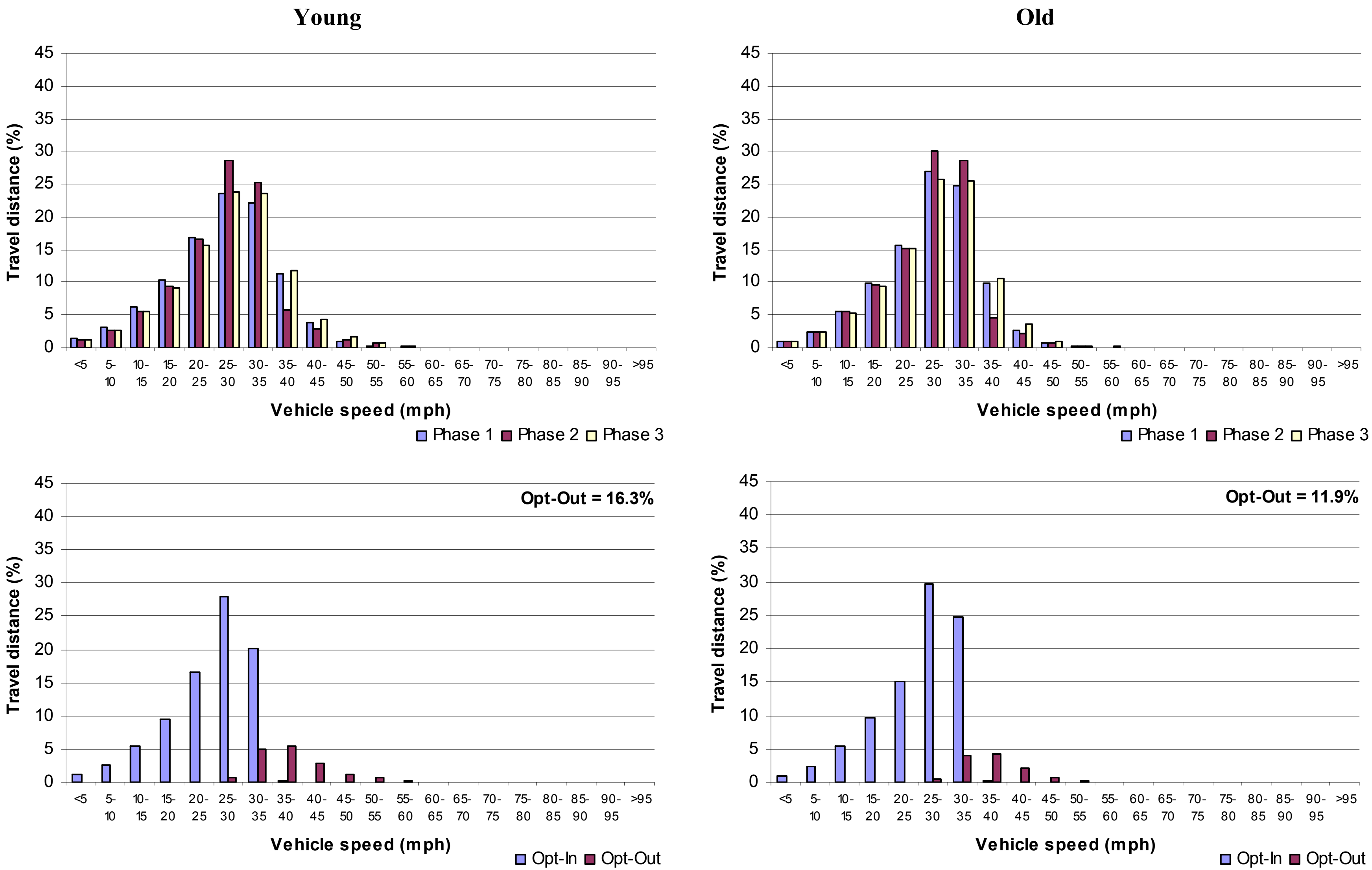


Figure 70: Comparison of the speed distribution in 30 mph zones between age groups

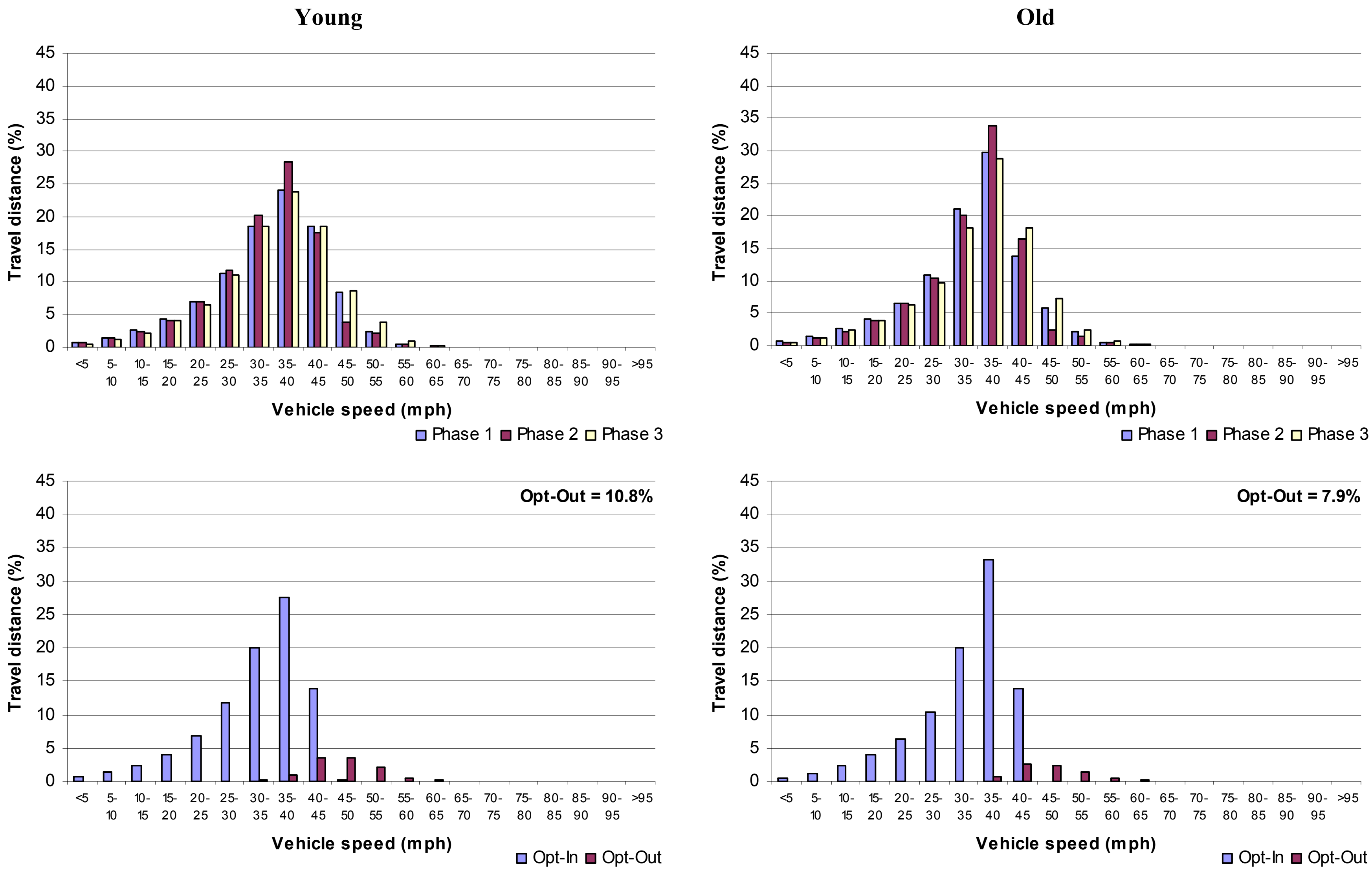


Figure 71: Comparison of the speed distribution in 40 mph zones between age groups

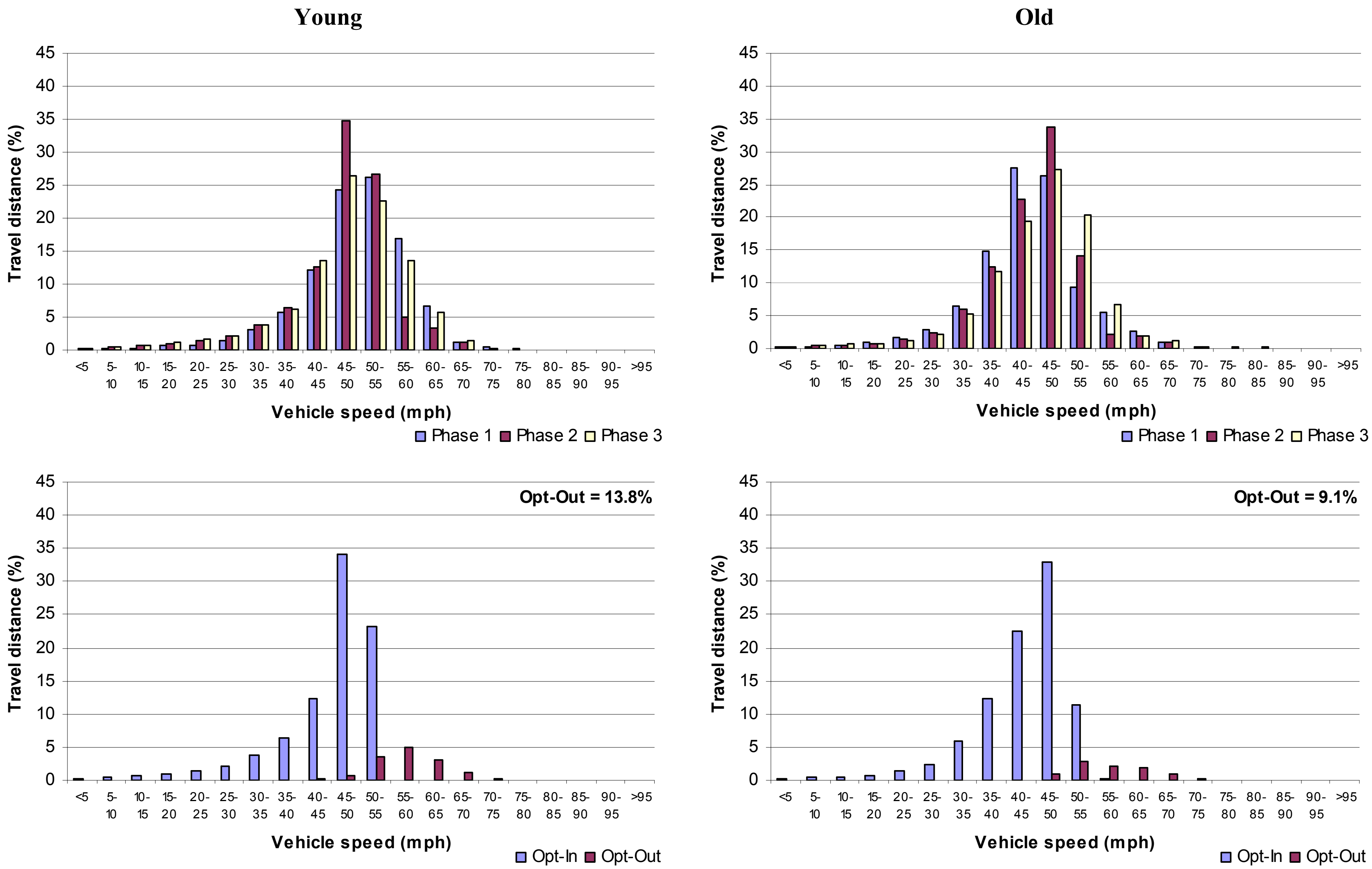


Figure 72: Comparison of the speed distribution in 50 mph zones between age groups

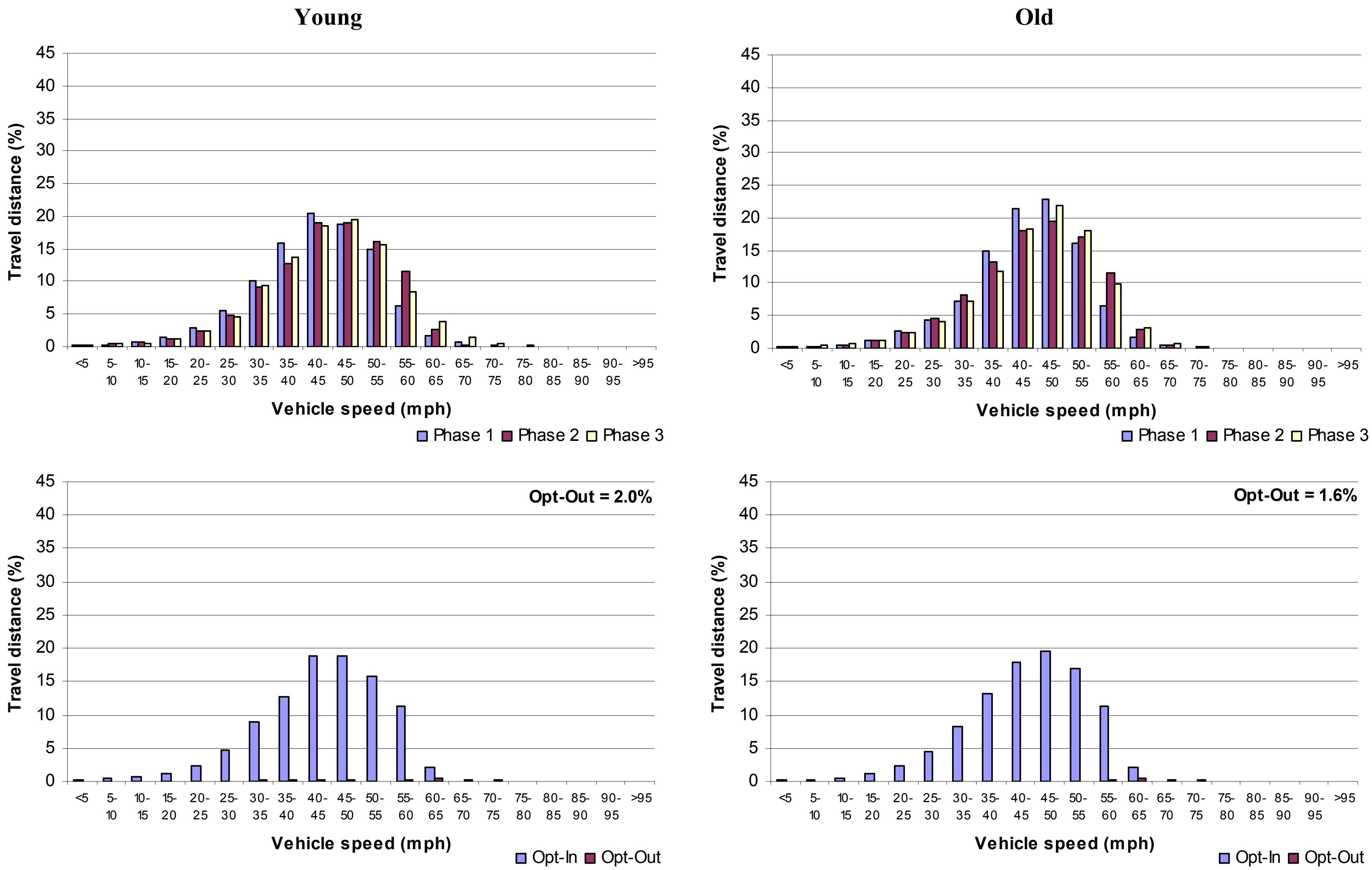


Figure 73: Comparison of the speed distribution in 60 mph zones between age groups

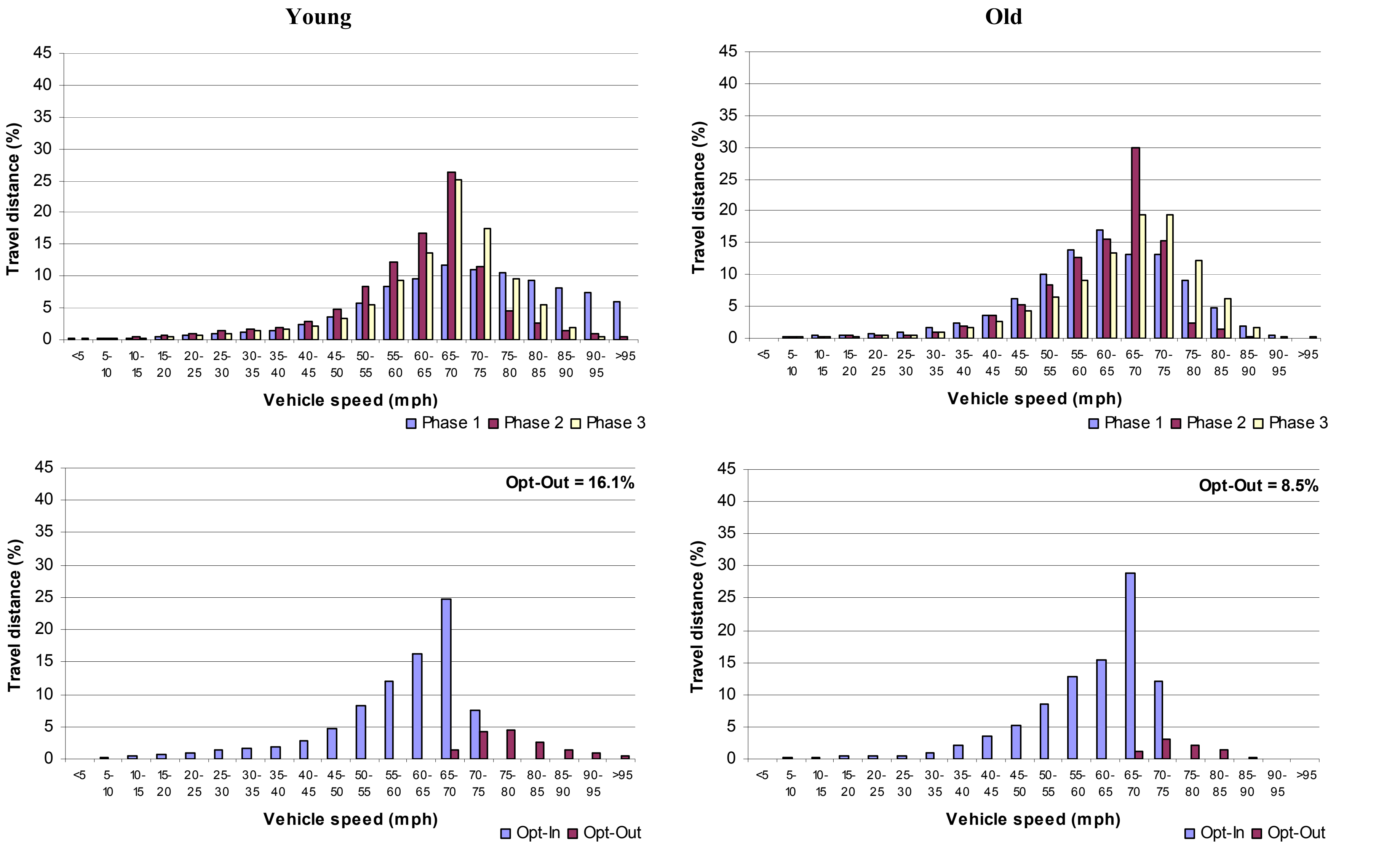


Figure 74: Comparison of the speed distribution in 70 mph zones between age groups

Figure 75 compares the mean and the 85th percentile across trial phases in each speed zone between the two age groups. Again as previously observed, ISA led to a 'V' shape across speed zones and gender groups, with only a few exceptions which were presumably attributable to differences in participants' reference for choice of speed across trial phases.

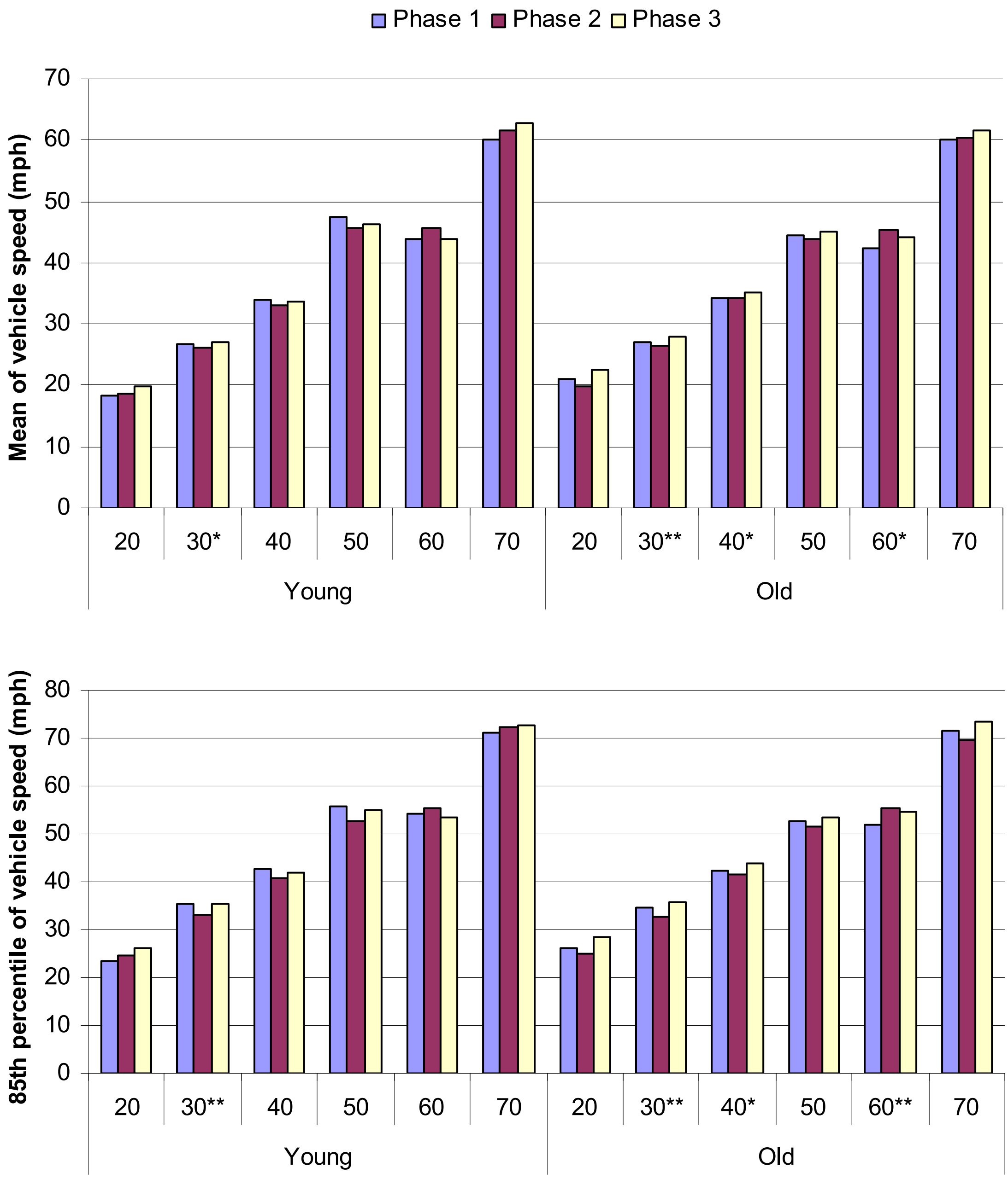


Figure 75: Comparison of key statistics of the speed distribution across trial phases between age groups

A series of repeated measures ANOVAs were carried out to confirm the difference across trial phases in individual speed zones; significant results are annotated in Figure 75 while detailed test results are given in Appendix D. ISA appeared to have a greater effect on older participants.

5.5.3 Intention to speed

Table 31 depicts a breakdown of vehicle kilometres across trial phases, speed zones and participants' intention to speed, and shows that non-intenders contributed much longer travel distance than intenders. Figure 76 further compares the distribution of travel distance between the two groups, and reveals quite different travel patterns across the two groups of participants. Both groups drove most frequently in the 30 mph zones but intenders spent a larger proportion of their travel distance in the 70 mph zones in comparison with non-intenders. This suggests that non-intenders drove in urban environment relatively more often than intenders.

Table 31: Vehicle kilometres across intention groups, trial phases and speed zones

Speed zone	Intender			Non intender		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
20 mph	22	59	20	100	321	85
30 mph	4,792	15,192	4,733	5,402	21,425	5,237
40 mph	1,964	6,774	2,240	3,109	12,300	3,115
50 mph	426	1,641	475	726	4,203	1,156
60 mph	450	2,657	660	1,708	8,682	2,076
70 mph	2,984	10,279	3,903	2,298	12,173	3,309
Sum	59,272			87,425		

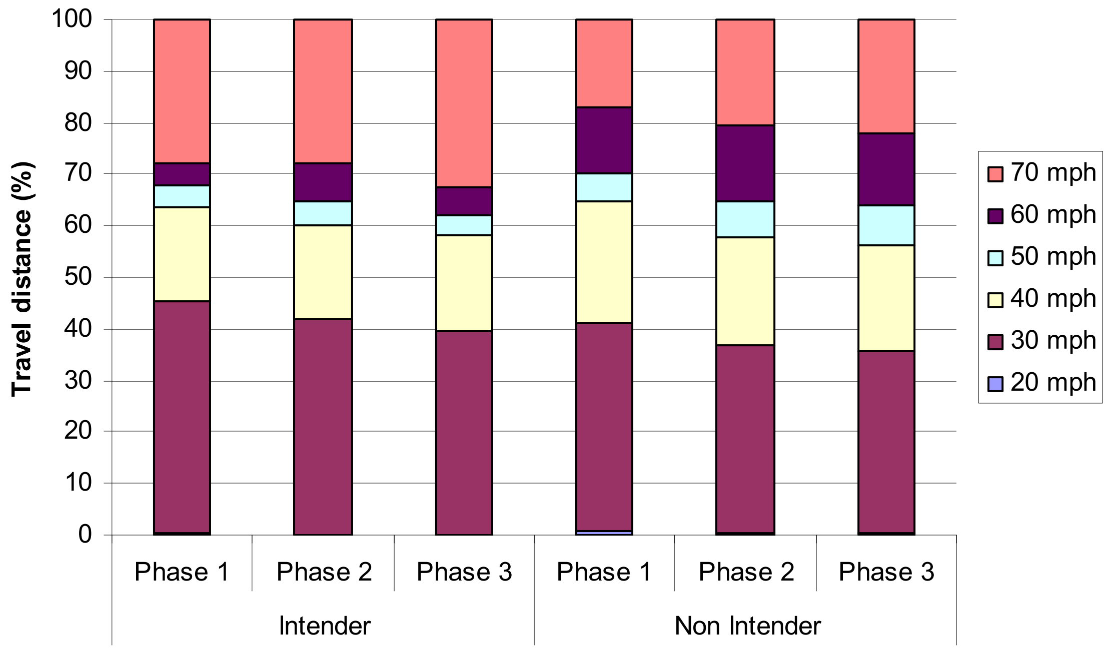


Figure 76: Comparison of patterns of travel distance between intention groups

Figure 77 through Figure 82 compare speed distribution across trial phases between the two groups. ISA effectively reshaped the speed distribution for both groups across speed zones but intenders were observed to have overridden the system more frequently than non-intenders across all speed zones.

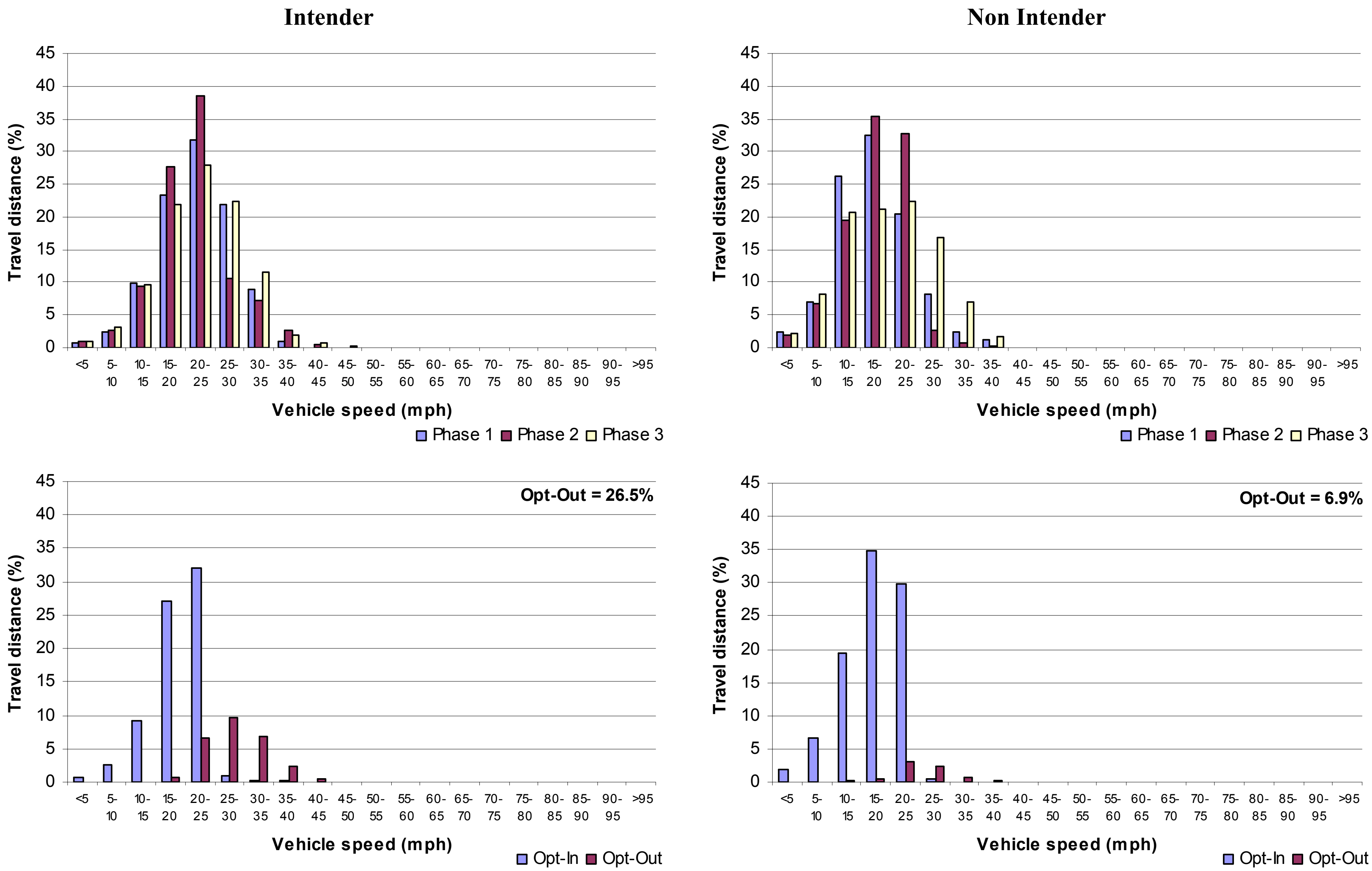


Figure 77: Comparison of the speed distribution in 20 mph zones between intention groups

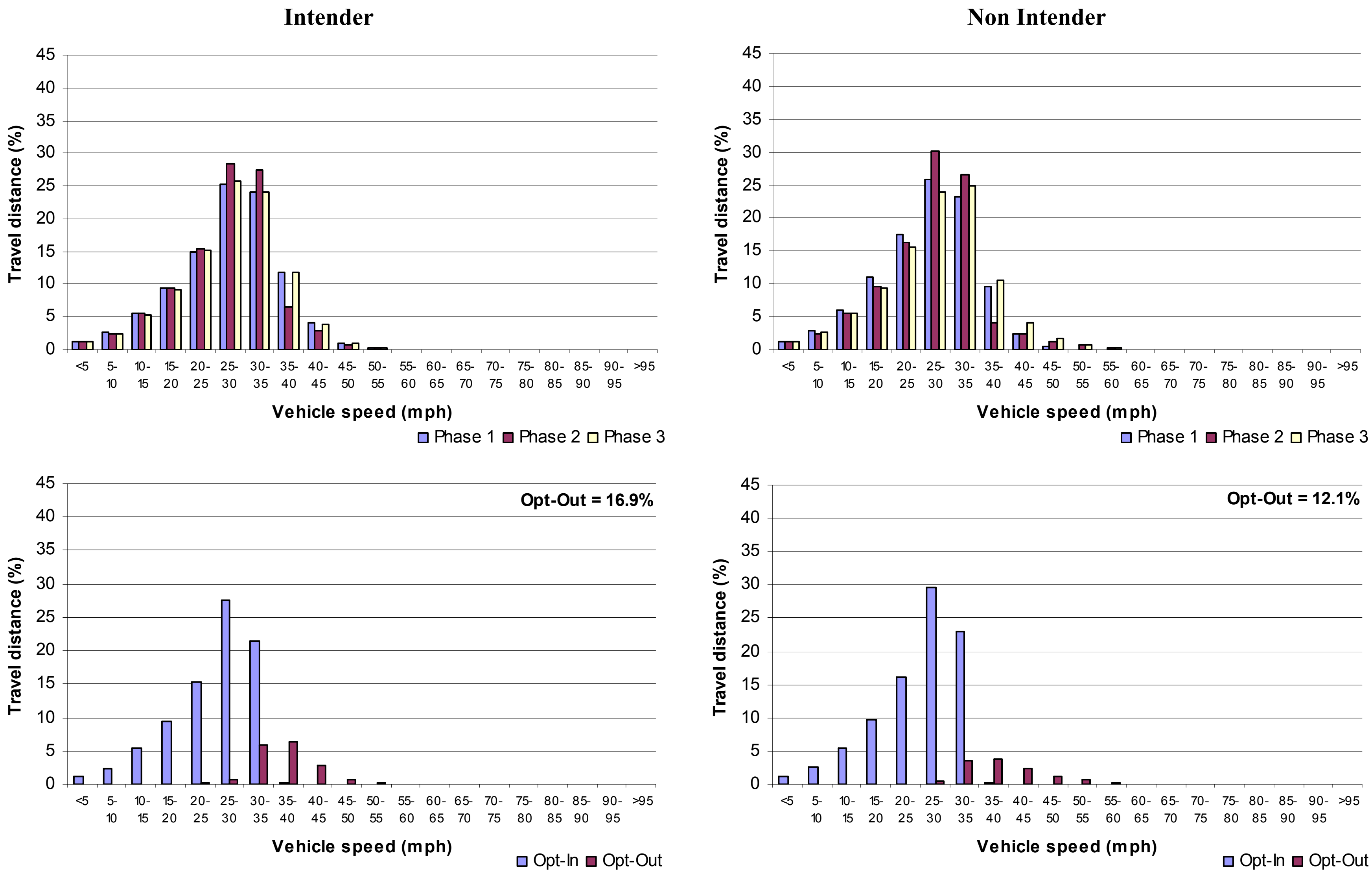


Figure 78: Comparison of the speed distribution in 30 mph zones between intention groups

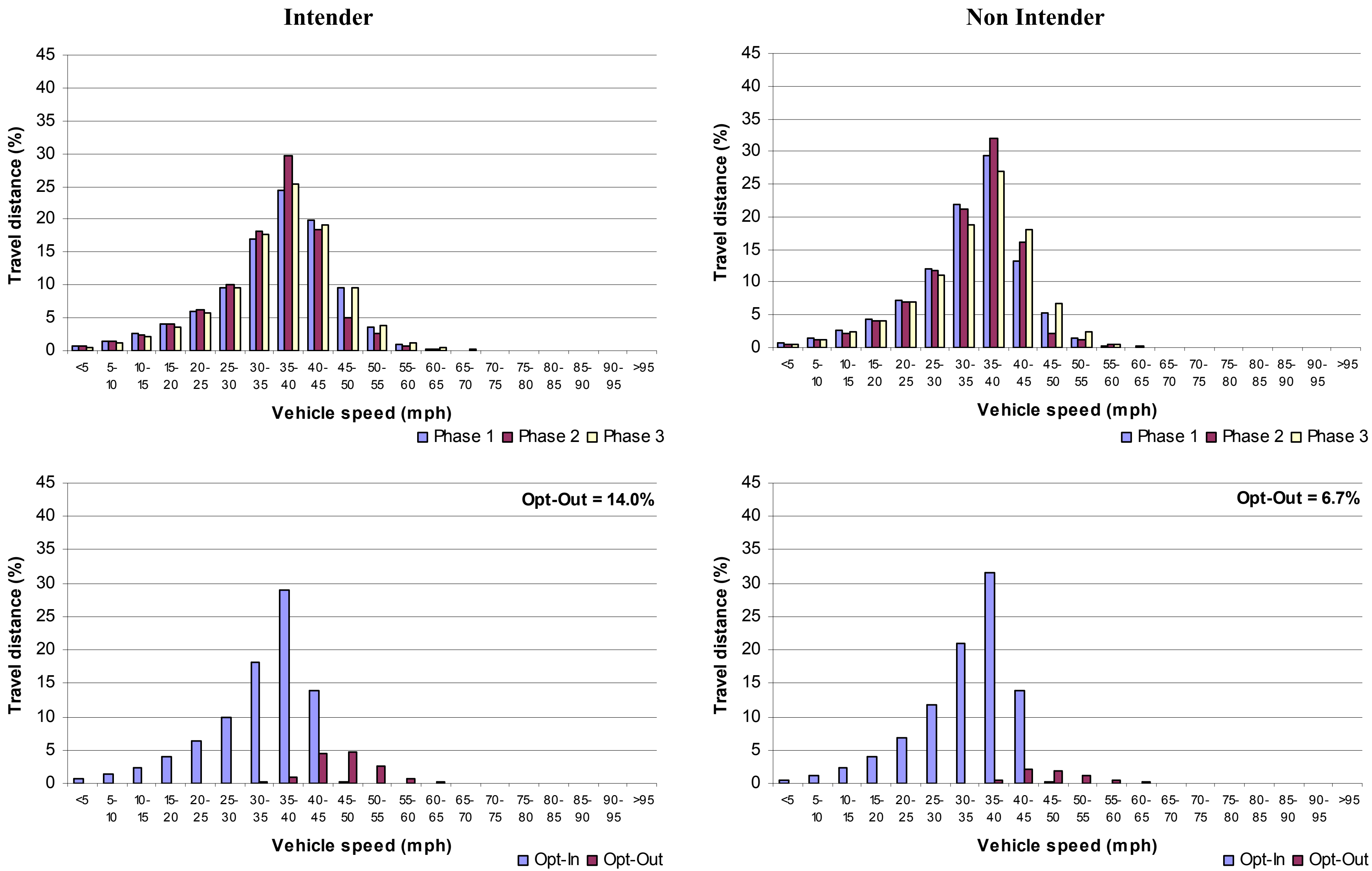


Figure 79: Comparison of the speed distribution in 40 mph zones between intention groups

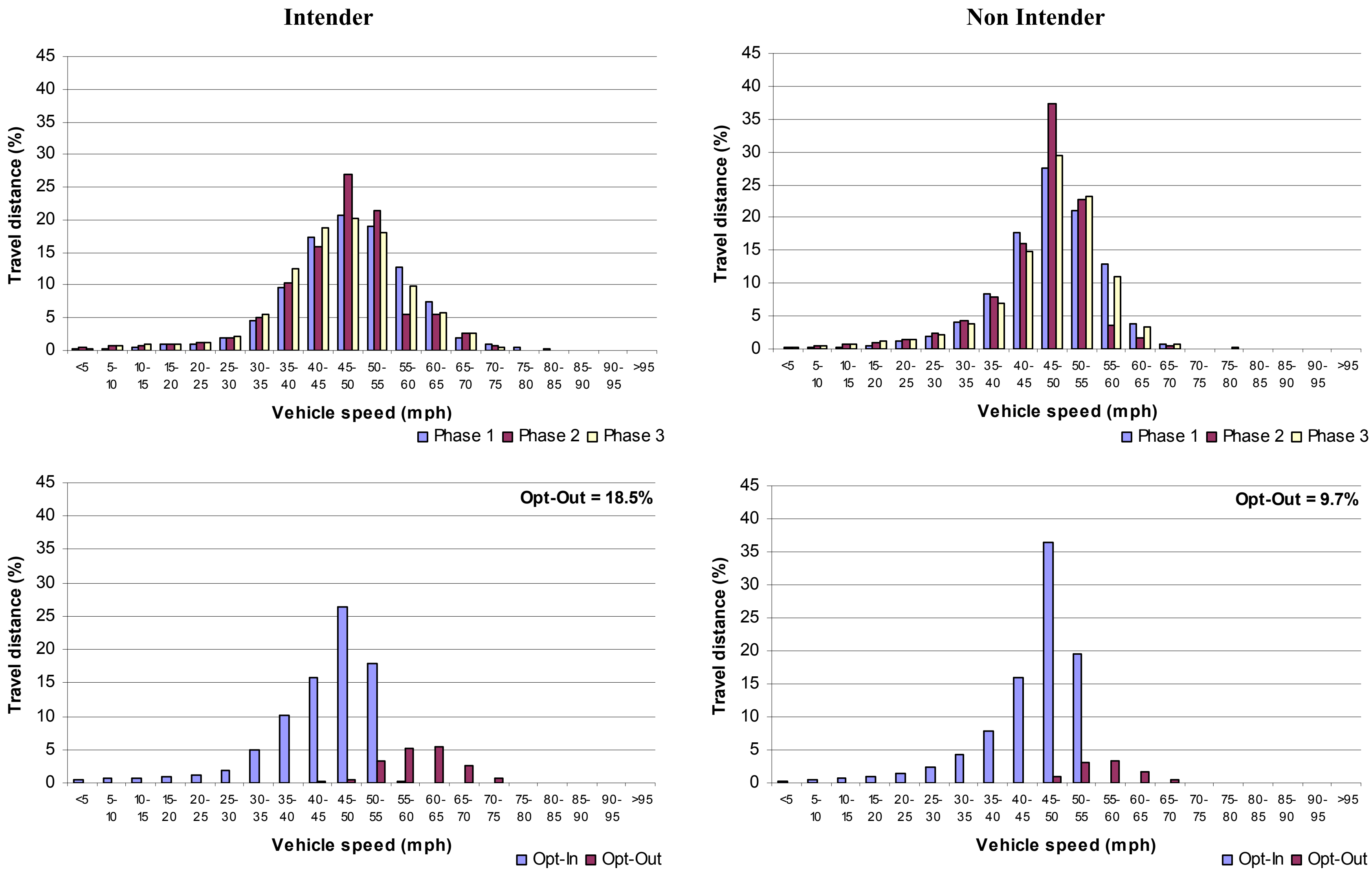


Figure 80: Comparison of the speed distribution in 50 mph zones between intention groups

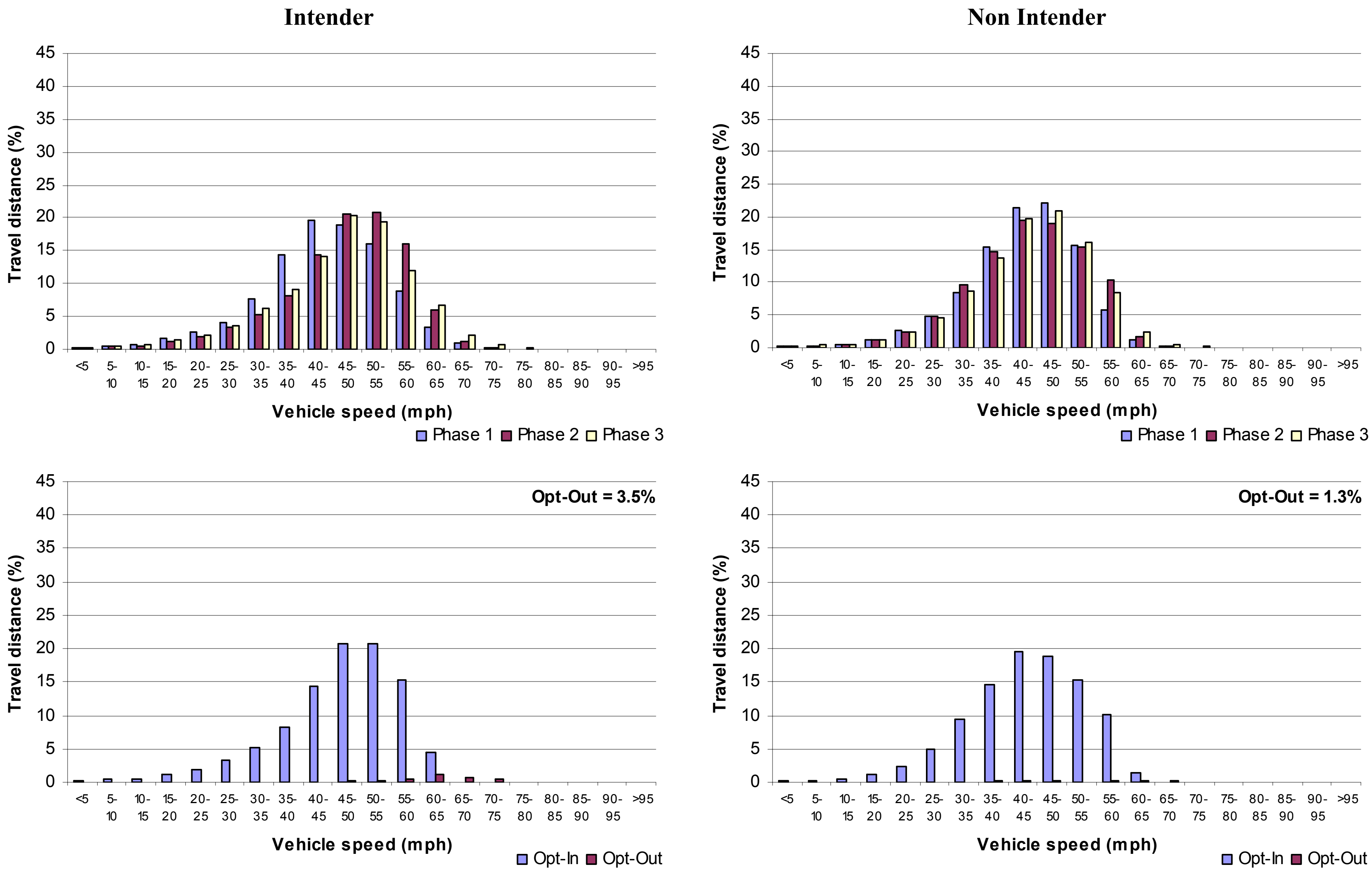


Figure 81: Comparison of the speed distribution in 60 mph zones between intention groups

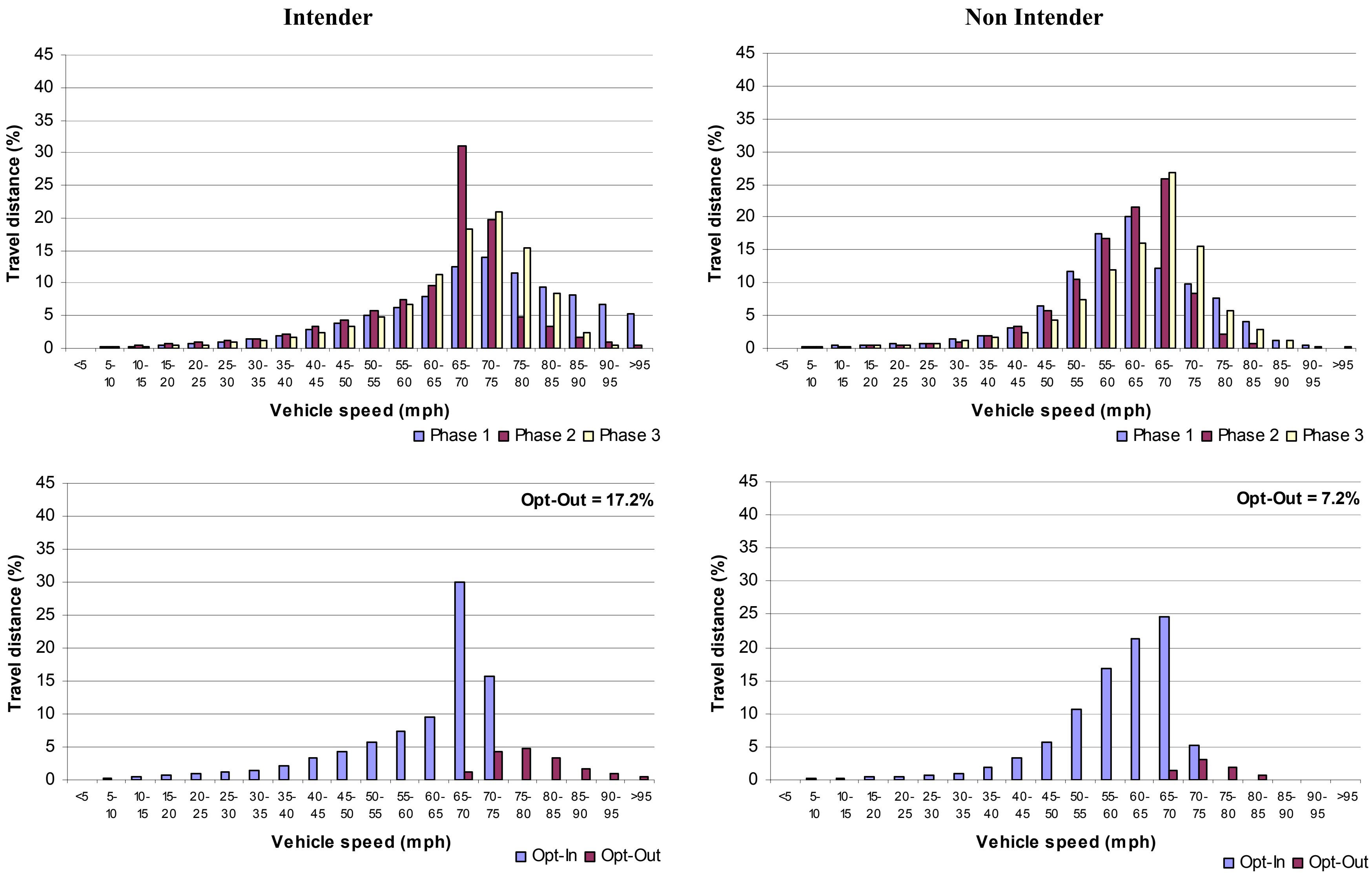


Figure 82: Comparison of the speed distribution in 70 mph zones between intention groups

Figure 83 compares the mean and the 85th percentile across trial phases in each speed zone between the two groups of participant. As can be seen, ISA led to a 'V' shape across speed zones and intention groups, with only a few exceptions. Apart from the usual distortion in the 60 and the 70 mph zones, the mean speeds across trial phases for the non-intender group also show a slightly different trend in the 40mph and 50mph zones; these differences however did not lead to statistical significance. In addition, these comparisons suggest that intenders generally demonstrated higher mean speeds and higher 85th percentiles.

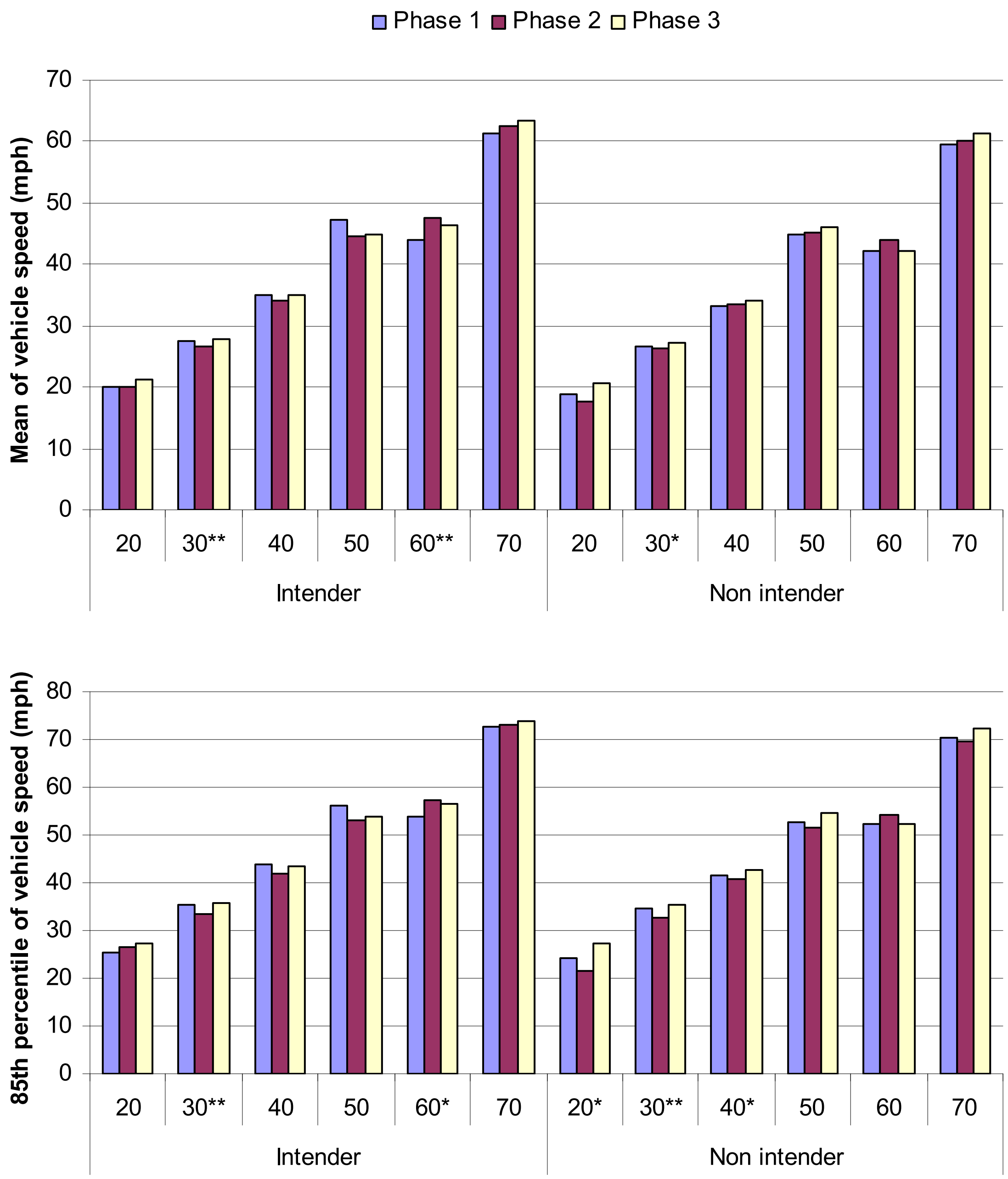


Figure 83: Comparison of key statistics of the speed distribution across trial phases between intention groups

A series of repeated measures ANOVA were carried out to confirm the differences across trial phases in individual speed zones; significant results are annotated in Figure 83 although detailed test results are given in Appendix D. As shown in Figure 83, ISA seemed to have a greater effect on non-intenders especially within lower speed zones.

5.5.4 The effect of ISA on demographic groups

As presented in the previous three sections, ISA intervention influenced the shape of the speed distribution across demographic groups and led to a 'V' shape on comparison of key statistics across trial phases in most of the speed zones. Overriding behaviours were clearly distinguishable across speed zones with respect to each pair of demographic groups. Figure 84 compares participants' overriding behaviour in general, highlighting that young, male intenders overrode the ISA system more than their counterparts. Noticeably the largest difference was between male and female participants. Considering that these groups of participants also demonstrated slightly higher mean and 85th percentile values of speed distribution than their counterparts, it seems that ISA was overridden by those drivers who need it most.

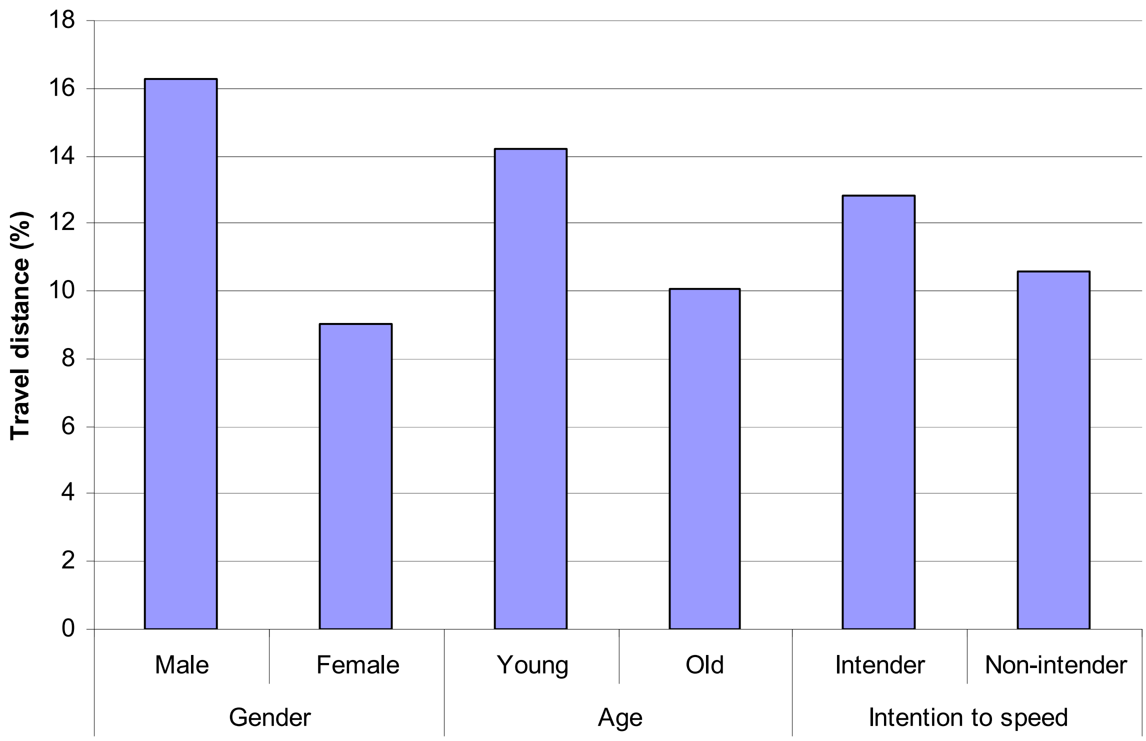


Figure 84: Comparison of overriding behaviour across demographic groups

The effectiveness of the ISA system could therefore be enhanced if compliance within the young, male and intender groups is encouraged and improved. Identification of key beliefs relating to system use such as those highlighted in Section 4.2 will therefore provide valuable additions to safety campaigns.

5.6 Discussion

Based on the analyses presented in this chapter, the ISA system leads to a distinctive effect in terms of transformation of the speed distribution. When ISA was switched on, a large proportion of the speed distribution initially spread over the speed limits was shifted to around or below the speed limit. The ISA system not only stops excessive speeding, but also leads to a reduction in speed variation, which would contribute to a reduction in accident occurrence.

The current design of an overridable system also highlights the value of a mandatory ISA system or incentives to encourage compliance with the ISA system. In particular, the highest occurrence of system being overridden happened in urban environment where speed management is crucial for road safety. Additionally, it was revealed that male drivers, young drivers, and drivers who intend to break speed limits overrode the system more often than female driver, old drivers, and drivers with less intention to break speed limits.

6. OBSERVATION DRIVES

6.1 Introduction

The primary purpose of the observation drives was to assess driver behavioural changes across the trial phases by means of indicators not available from the logged data. Participants were accompanied by two trained observers around a predetermined evaluation route on four separate occasions. Since the four drives were carried out on an identical route, it also provided an opportunity to assess the effect of the ISA system on trip related measures.

The next section describes the methodology developed for the observation drives, followed by analysis results and discussion.

6.2 Methodology

6.2.1 The trial route

The route was laid in West Yorkshire, around 38 miles long, and took approximately 1 hour to complete. It covered a variety of driving environments (i.e. urban, rural, and motorway), road layout (i.e. single and dual carriageway), and speed zones (i.e. 30, 40, 50, 60, and 70 mph), which allowed drivers' interactions with other road users across a wide range of traffic conditions to be recorded by the two observers in the vehicle.

6.2.2 Trial scheduling

The timing of the observation drives is illustrated in Figure 15 in Section 3.1 and is based on the following rationale.

Observation 1 (OB1): this took place at the end of Phase 1. As Phase 1 refers to no ISA intervention, OB1 served as baseline for comparison across the four Observation Drives.

Observation 2 (OB2): this took place at the end of the first month of Phase 2, when participants had one month experience on the ISA system.

Observation 3 (OB3): this took place at the end of Phase 2, when participants had experienced the ISA system over 4 months.

Observation 4 (OB4): this took place at the end of Phase 3, when participants had driven for a month without ISA intervention following their ISA experience.

6.2.3 Wiener Fahrprobe technique

The recording technique used for the observation drives was adapted from the Wiener Fahrprobe "Vienna driving test" (Risser, 1985). The Wiener Fahrprobe coding forms record a wide variety of driver behaviour, either positive or negative, across different road geometry layouts such as links and junctions. The test route designed for Trial 1 was broken into 37 sections and a coding form was used for each section. An overall score from a participant per drive was subsequently derived by summing up the frequency of negative driving behaviours across all sections. Hence the higher the overall score, the higher the numbers of negative driving behaviours committed during the observation drives. An example sheet of the Wiener Fahrprobe coding forms is given in Appendix E.

6.2.4 Mental workload

The NASA-RTLX (RTLX; Byers, Bittner and Hill, 1989) provided a measure of subjective workload. This tool involved formalising the driver's own judgement about the workload he/she experienced based on the assumption that workload is influenced by six workload dimensions, i.e. mental demand, physical demand, temporal demand, performance, frustration level and effort. Drivers placed a line on a bipolar scale (low-high) indicating their experience of each dimension. The score was simply taken as the length (in mm) from the left scale anchor. A high score represented a strong experience of each dimension (e.g. drivers experienced a high level of frustration when driving). RTLX has been widely used for tapping subjective workload (e.g. Nygren, 1991; Ashby, Fairclough and Parkes, 1991; Marin-Lamellet et al, 1994; Comte, 2000).

6.3 Results

6.3.1 Trip related measures

Figure 85 shows comparison of trip related measures across the four Observation Drives, which demonstrates that ISA led to reduced maximum speed, longer travel time, and better fuel economy. The significance of the difference is confirmed by the test results of repeated measures ANOVA, as depicted in Table 32.

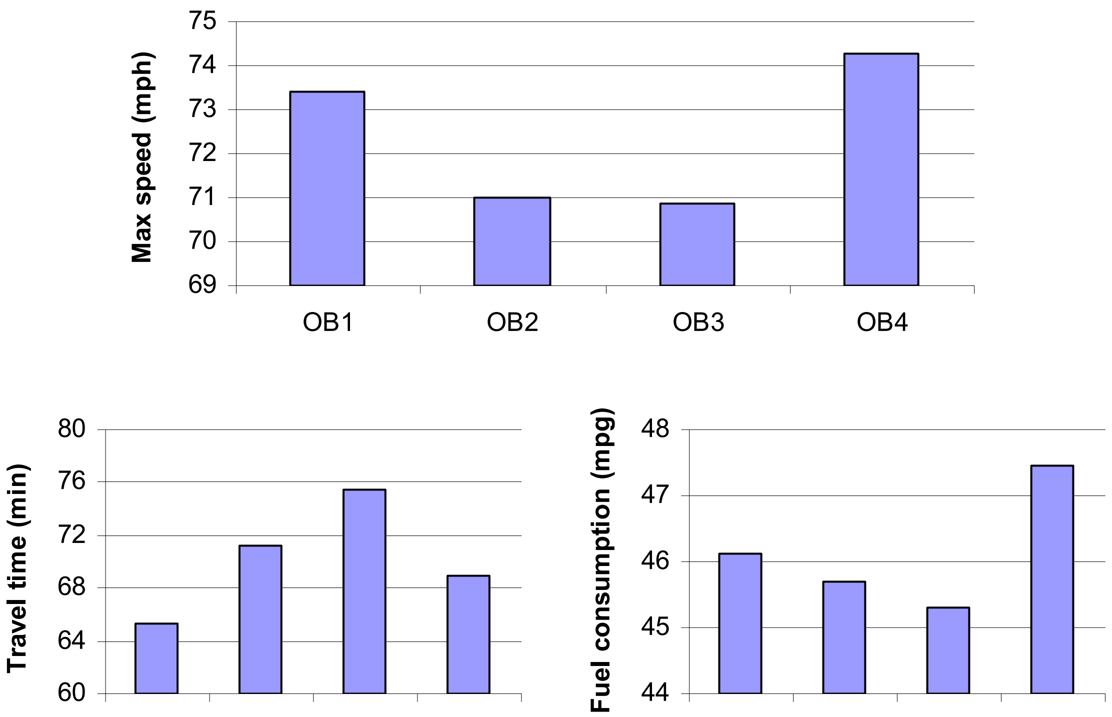


Figure 85: Comparison of trip related measures across trial phases

Table 32: Results of ANOVA and post-hoc t-test of trip related measures

	OB1	OB2	OB3	OB4	Repeated measures ANOVA: *F* statistic	*p* value	Post-hoc t-test			
Mean travel time (SD)	65.30 (5.42)	71.19 (8.90)	75.45 (7.53)	69.01 (4.84)	F(3,54) = 3.38	0.025*		OB2	OB3	OB4
							OB1	*	*	*
							OB2		×	×
							OB3			*
Max speed (SD)	73.40 (5.49)	70.98 (3.55)	70.88 (4.10)	74.28 (5.84)	F(3,54) = 4.79	0.005**		OB2	OB3	OB4
							OB1	*	*	×
							OB2		×	*
							OB3			**
MPG (SD)	46.13 (3.30)	45.71 (4.09)	45.31 (4.16)	47.44 (1.73)	F(3,54) = 1.92	0.046*		OB2	OB3	OB4
							OB1	×	*	*
							OB2		×	*
							OB3			*

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant.

It is worth nothing that the analysis of fuel consumption presented in Section 5.3 was based on all trips made in individual phases with no warranty that trip characteristics were comparable across phases and hence did not reveal clear trends. The analysis of fuel consumption described in this section was based on identical trips and therefore other factors which may affect fuel economy among trips such as trip length were eliminated.

6.3.2 Observed driving behaviour

Figure 86 illustrates mean Wiener Fahrprobe scores across the four Observation Drives, which shows a significant drop in the number of observed negative behaviour from OB1 to OB2, a further slight drop from OB2 to OB3, then an increase from OB3 to OB4. The ANOVA test results presented in Table 33 reveal that the Wiener Fahrprobe scores recorded when ISA was turned on (i.e. OB2 and OB3) were reliably lower than when ISA was turned off.

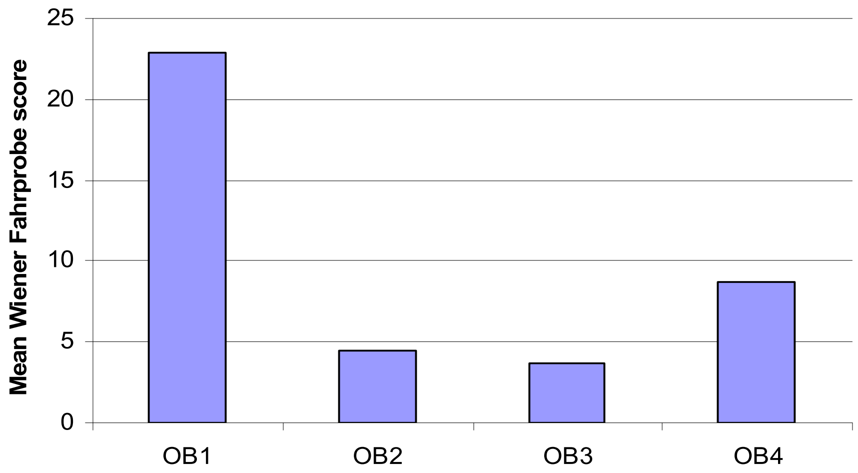


Figure 86: Mean Wiener Fahrprobe score across trial phases

Table 33: Results of ANOVA and post-hoc t-test of Wiener Fahrprobe score across trial phases

	OB1	OB2	OB3	OB4	Repeated measures ANOVA					
					F statistic	*p* value	Post-hoc t-test			
								OB 2	OB 3	OB 4
Mean (SD)	22.85 (23.74)	4.50 (3.42)	3.65 (2.99)	8.70 (7.93)	F(3,57) = 11.49	< 0.0005**	OB1	**	**	**
							OB2		×	*
							OB3			*

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant.

Figure 87 shows two negative behaviours recorded on the Wiener Fahrprobe forms, in which the bars stand for total frequency of the negative behaviour observed from all participants rather than mean values. As indicated by the left half of the figure, participants showed considerable improvement in inappropriate choice of speed in response to road geometry when ISA was turned on. In contrast, the right half of the figure suggests negative implications of introducing ISA. The trend of changes across the four drives corresponds to the trend revealed by the graph comparing travel time in Figure 85, which suggests that participants might try to compensate for their loss in travel time by jumping the amber light.

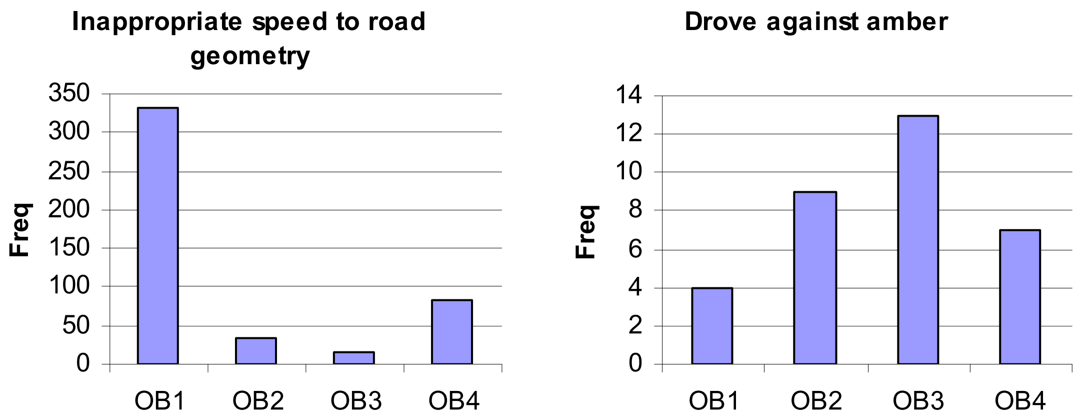


Figure 87: Observed negative driving behaviour across trial phases

Figure 88 presents comparison of mean Wiener Fahrprobe scores across the four observation drives with respect to demographic groups, which reveals similar patterns across groups, i.e. the ISA system led to fewer negative driving behaviours for all groups of drivers. The significance of the changes over time was confirmed by repeated measures ANOVA as presented in Table 34. It is however worth noting that the magnitude of improvement varies between the two sub-groups within each demographic groups. For instance, male participants showed more prominent improvement than female participants, which was preliminarily because male participants committed more negative driving behaviour during the baseline as opposed to female participants. Similar patterns were also revealed by comparing young against old participants, and intenders against non-intenders. In addition, when ISA control was removed, old participants seemed to resume their negative driving habit more quickly than young participants. Similarly, intenders returned to more negative driving behaviours than non-intenders.

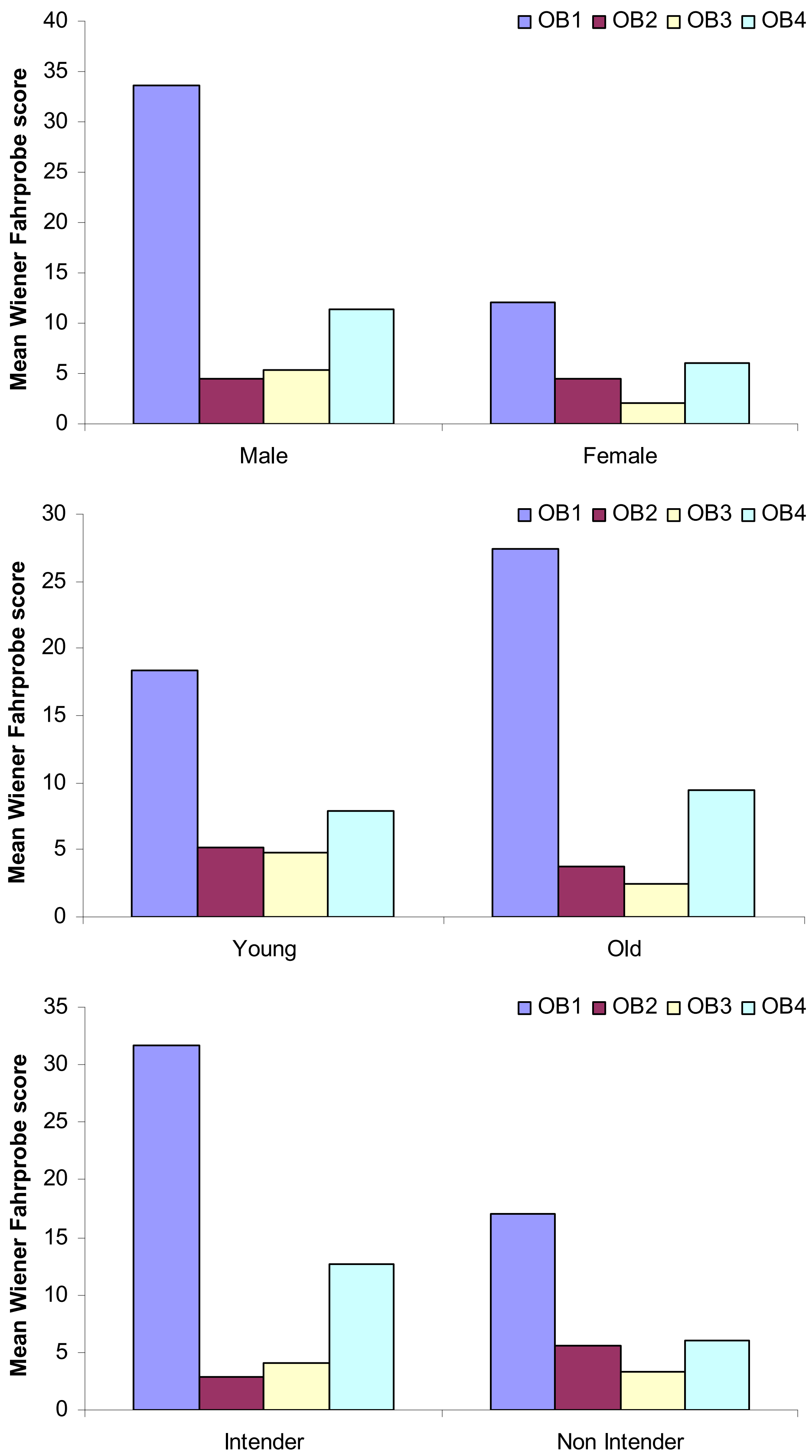


Figure 88: Mean Wiener Fahrprobe score across trial phases in terms of demographic groups

Table 34: Results of ANOVA and post-hoc t-test of Wiener Fahrprobe score across trial phases in terms of demographic groups

Demographic group		OB1	OB2	OB3	OB4	ANOVA	Post-hoc t-tests			
								OB2	OB3	OB4
Gender	Male	33.7 (28.9)	4.5 (3.4)	5.3 (2.8)	11.4 (10.2)	**	OB1	*	*	*
							OB2		×	×
							OB3			×
								OB2	OB3	OB4
	Female	12.0 (9.4)	4.5 (3.5)	2.0 (2.2)	6.0 (3.5)	**	OB1	*	*	×
							OB2		*	×
							OB3			*
								OB2	OB3	OB4
Age	Young	18.3 (21.1)	5.2 (3.2)	4.8 (2.6)	7.9 (5.7)	**	OB1	*	*	*
							OB2		×	×
							OB3			×
								OB2	OB3	OB4
	Old	27.4 (26.3)	3.8 (3.6)	2.5 (3.0)	9.5 (9.9)	**	OB1	*	*	*
							OB2		×	*
							OB3			*
								OB2	OB3	OB4
Intention to speed	Intender	31.6 (28.6)	2.9 (2.2)	4.1 (2.9)	12.6 (10.0)	**	OB1	**	**	*
							OB2		×	*
							OB3			×
								OB2	OB3	OB4
	Non intender	17.0 (18.9)	5.6 (3.7)	3.3 (3.0)	6.1 (5.0)	**	OB1	*	*	*
							OB2		×	×
							OB3			×

Note:
1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant.

6.3.3 Subjective mental workload

As RTLX contains multiple scales, reliability analysis was carried out to confirm internal consistency among the six rating scales based on inter-item correlation; the results are presented in Table 35. The inter-item correlation between RTLX's sub scales was strong in OB1 and OB2, but was weaker in OB3 and OB4. It is worth noting that stronger inter-item correlation suggests that participants rated their perceived workload more consistently across the six workload dimensions, while weaker inter-item reliability suggests that participants showed stronger feelings on certain workload dimensions over the rest, but it does not invalidate the data.

Table 35: Reliability scores for NASA-RTLX measures

	OB1	OB2	OB3	OB4
Cronbach's Alpha (α)	0.72	0.67	0.47	0.31

Figure 89 shows the overall workload scores across trial phases, which indicates that workload increases when driving under the ISA system. Changes in the perceived workload across trial phases suggest that participants initially felt the driving task became more demanding in the presence of the ISA system (i.e. workload score increased from OB1 to OB2), but with prolonged experience, they gradually adapted to the system and workload decreases accordingly (i.e. workload score dropped slightly from OB2 to OB3). When the ISA system was no longer present, participants' perceived workload went back to similar levels to the baseline (i.e. comparing OB4 against OB1). To confirm statistical significance of the changes in participants' perceived workload, repeated measures ANOVA with gender, age and intention group serving as between-subject factors was carried out. The results indicated that the changes were significant at the 0.05 significance level ($F(3, 48) = 3.067$, $p = 0.037$). Post hoc analysis revealed that participants experienced significant greater workload during OB2 than OB4.

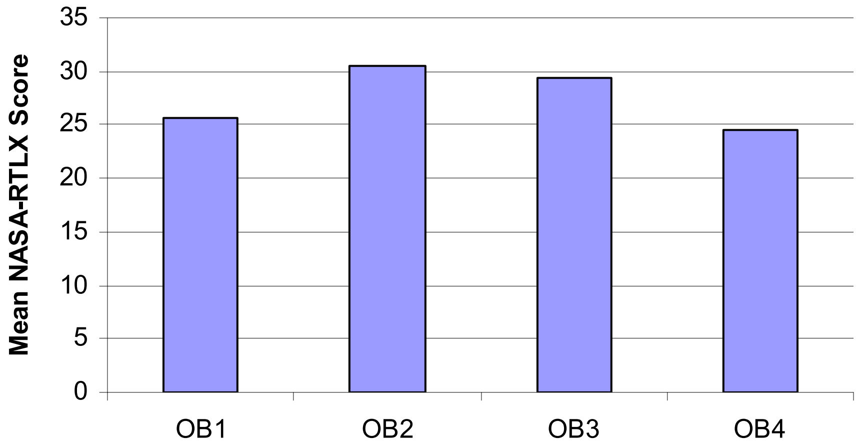


Figure 89: Mental workload scores over time

Figure 90 presents the mean scores of individual workload dimensions across the trial phases, which demonstrates a very similar pattern to that for overall workload scores as shown in Figure 89. Participants' perceived workload increased when ISA was introduced and decreased when ISA control was removed, apart from 'Own Performance' in which OB4 led to the highest score, and 'Time Pressure' as well as 'Frustration' in which OB3 led to worse results than OB2.

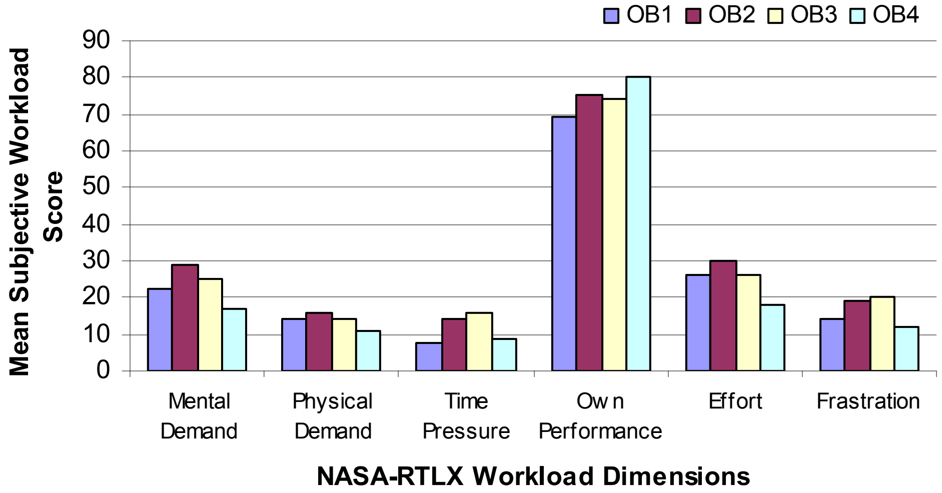


Figure 90: Individual dimension workload scores over time

Repeated measures ANOVA with gender, age and intention group serving as between-subject factors was employed to confirm the changes in workload scores over time. However, none of the workload dimensions showed significant effect over time (Mental Demand scores: $F(3, 48) = 2.465$, $p = 0.074$; Physical Demand scores: $F(3, 48) = 0.939$, $p = 0.429$; Time Pressure scores: $F(3, 48) = 4.248$, $p = 0.023$; Own Performance scores: $F(3, 48) = 1.227$, $p = 0.310$; Effort scores: $F(3, 48) = 2.264$, $p = 0.104$; Frustration scores: $F(3, 48) = 1.896$, $p = 0.143$).

6.4 Discussion

The data collected from the Observation Drive have demonstrated some distinctive effect of introducing ISA on driver behaviour as follows.

- Reduced overall negative driving behaviour
- Reduced frequency of inappropriate choice of speed
- Reduced maximum vehicle speed

An added benefit of increased fuel economy was also suggested by the data. In addition, travel time increased, presumably attributable to reduced speed violations. However, increased travel time seems also to be associated with increased number of traffic light violations.

Although changes in driver perceived workload across trial phases were not statistically significant, there were some indications of increased workload when ISA was turned on, which was associated with an increase in mental demand, time pressure, effort, and frustration.

7. CLUSTER TRIAL

7.1 Introduction

The purpose of the cluster trial was to create dense ISA traffic by manipulating the penetration rate of ISA vehicles in order to explore participants' responses to driving in a 'non-isolated' environment and to investigate the potential benefit of ISA to the entire traffic network. The ISA fleet drove a chosen route six times on a Sunday with different levels of penetration. The next section specifies the study design, followed by analysis results, and discussion.

7.2 Methodology

7.2.1 The trial route

The cluster trial was carried out on the A1079 between Dunnington and Shiptonthorpe as shown in Figure 91. The test route was approximately 10.5 miles long and it took about 15 minutes to drive from one end to the other. No roundabouts or signalised junctions were present on the test route. While there were unavoidably a few minor roads joining the test route, priority was always given to vehicles travelling on the test route. The aforementioned geometric conditions were considered upon choosing the candidate test route in order to minimise the interruption to the ISA platoon.

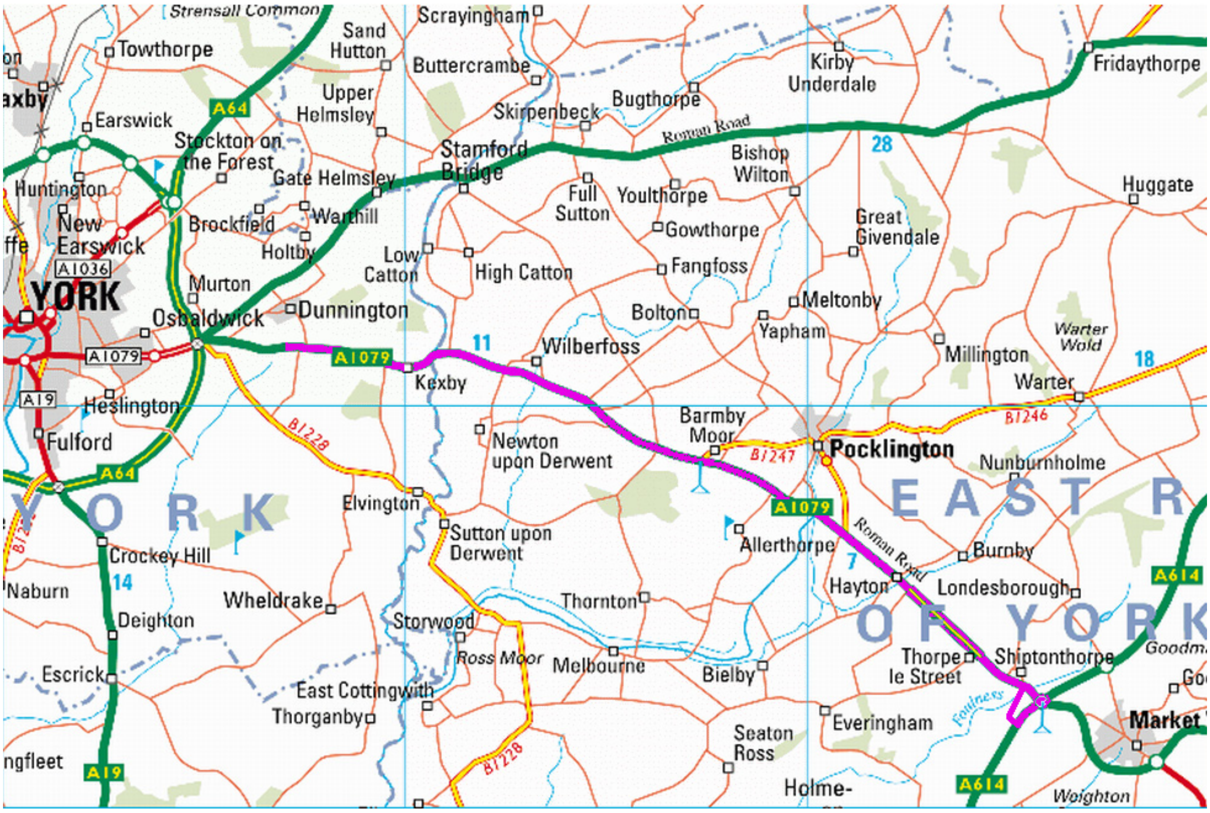


Figure 91: Map of the cluster trial route

7.2.2 Headway measurement

Three cameras were erected on the test route in order to monitor time headway of individual cars in the ISA platoon during each trial run. Camera sites were chosen on straight sections of the road in order to minimise headway variations introduced by unrelated factors such as geometric constraints which would affect the stability of vehicle speed as well as headway maintenance.

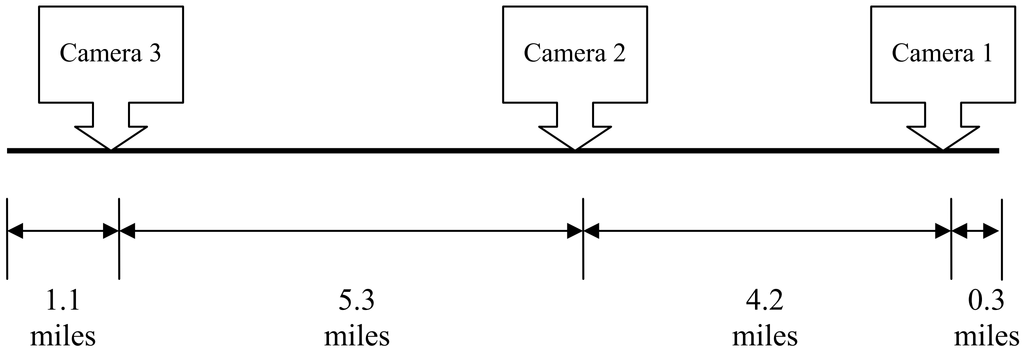


Figure 92: Camera positions on the cluster trial route

7.2.3 Driver responses

Driver responses to the manipulated dense ISA traffic were measured by questionnaires consisting of workload assessment and satisfaction with the ISA intervention, collected at the end of each trial run. User acceptance and opinions were also tapped at the end of the cluster trial.

7.2.4 Penetration manipulation

Various levels of ISA penetration was achieved by releasing ISA cars into the traffic following preset target values (e.g. 100%, 80%, 60%, etc). Depending on the traffic flow when a trial run was being carried out, the manipulated penetration varied to some extent between the start point and end point of the route. The achieved penetration rates are depicted in Table 36.

Table 36: Penetration manipulation in the cluster trial

Run ID	Penetration at					Average penetration
	Start point	Camera 1	Camera 2	Camera 3	End point	
6	41	41	41	42	42	41
3	63	55	48	41	33	46
1	71	60	56	50	52	58
5	67	71	71	71	67	69
4	100	100	86	75	71	86
2	100	100	86	75	75	87

Note: figures shown in cells are percentage.

7.3 Results

7.3.1 Time headway

Time headway of ISA cars to lead vehicles was derived by video transcription. Not all ISA cars have contributed to the analysis of time headway. When an ISA car was following a non-ISA vehicle, this ISA car was excluded from the analysis to eliminate possible distortion, i.e. the non-ISA leading vehicle might have greater speed variation and hence would contaminate the data pattern of the following ISA car's time headway.

Figure 93 compares the mean time headway of valid ISA cars across various levels of penetration manipulation. It shows that mean time headway generally decreased in line with an increase in ISA penetration, except for the mean time headway derived from penetration rate in the band of 70-80%, which was perhaps affected by other non-ISA cars within the ISA platoon.

Although a reduced headway may initially seem to be a concern for safety, the mean headway derived from the highest penetration band was still above the well-accepted safety criterion 'the two-second gap' (i.e. the Highway Code).

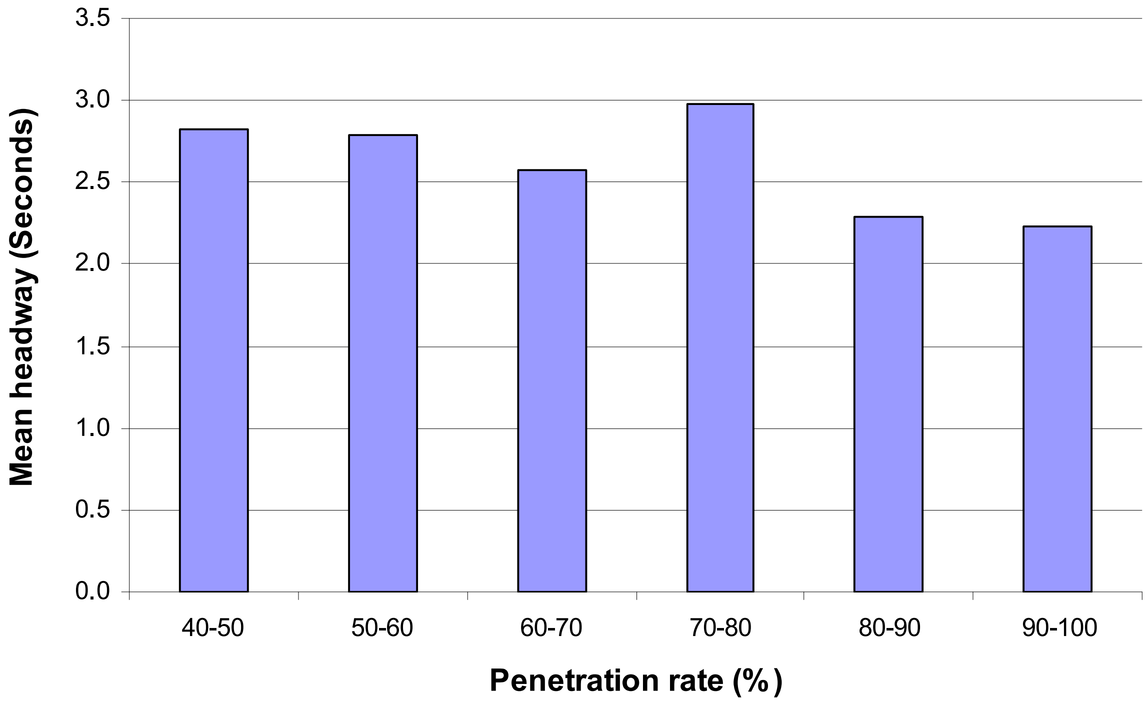


Figure 93: Mean time headway of ISA vehicles across penetration levels

Figure 94 demonstrates the correlation between mean time headway and ISA penetration. It can be seen that the R^2 value would be further improved if the outlier is removed. The relationship between headway and ISA penetration suggests that the headway of ISA cars would stabilise in line with an increase in ISA penetration.

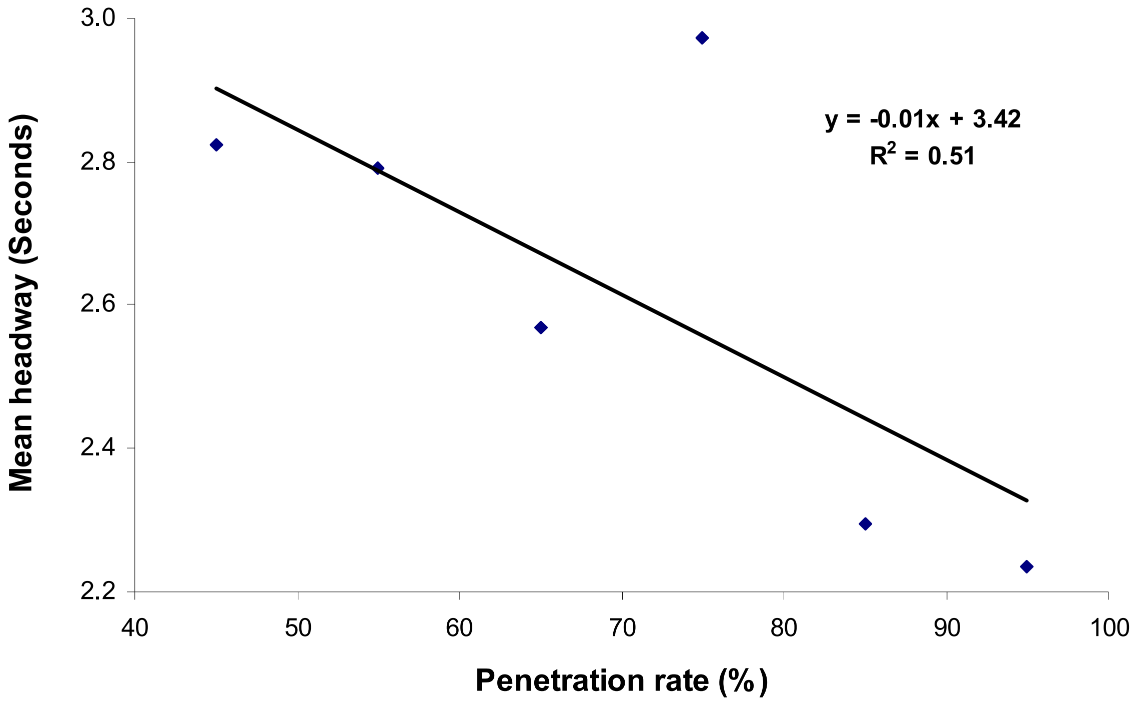


Figure 94: Correlation between mean time headway and penetration rate

7.3.2 Driver responses

The data obtained from questionnaires did not show a distinctive trend across ISA penetration rate, either in terms of the overall RTLX score or in terms of most of the individual dimensions. However, participants' perceived own performance increased in line with an increase in ISA penetration, as shown in Figure 95. Participants also seemed to be more satisfied with the ISA system along with increased penetration rate, as illustrated in Figure 96.

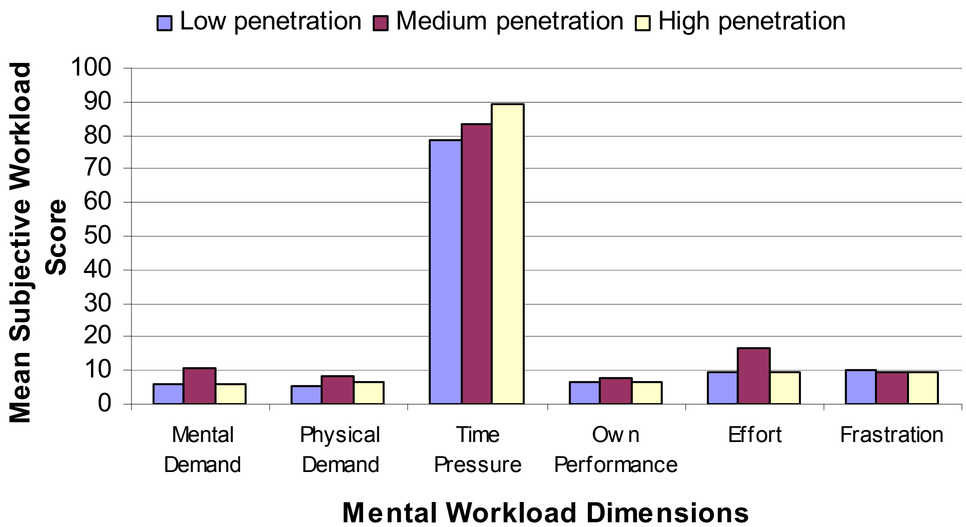


Figure 95: Driver mental workload in terms of ISA penetration

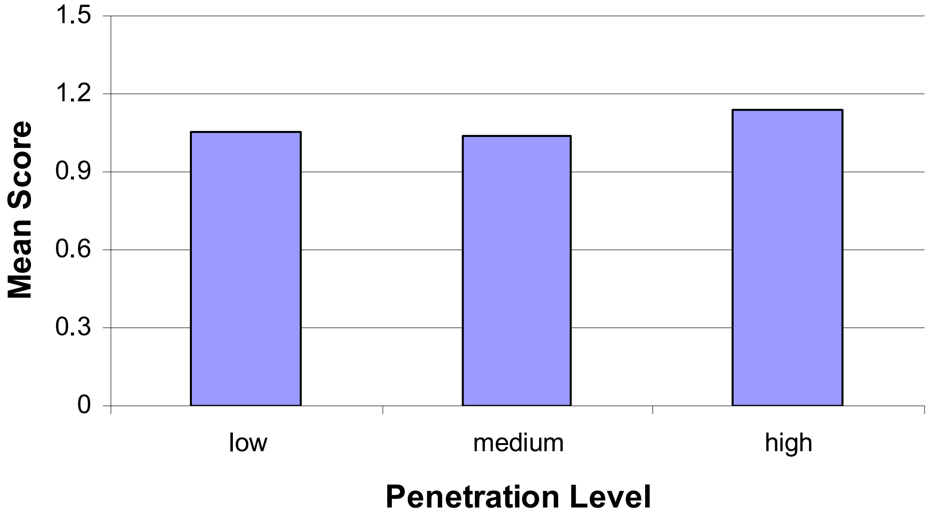


Figure 96: Driver satisfaction with the ISA system

Through post-trial questionnaires, participants expressed that they felt less pressure from other traffic during the day of the cluster trial in comparison with their daily driving. However, the experience of the cluster trial had not changed their acceptance of the ISA system.

7.4 Discussion

The cluster trial has led to encouraging results that increased ISA penetration may facilitate vehicle headway stabilisation. This finding obviously has positive implications for the entire traffic network. A more efficient traffic network will not only contribute to reductions in accident occurrence but also savings in social costs.

With individual drivers' reaction to an increase in ISA penetration, some participants felt more comfortable with ISA intervention in comparison with daily driving when they were an absolute minority. This cluster trial has however not led to clear evidence from the workload measures. Further evidence may be revealed with the data from the next cluster trial in Field Trial 3.

8. FURTHER ANALYSIS

Given that ISA has been shown to reduce speed variation, it is planned to use the logged vehicle data to analyse likely traffic conflicts during participants' daily driving in order to further investigate potential contributions of the ISA system to traffic safety. It has been widely argued that braking is the most common evasion manoeuvre in traffic conflicts, ranging from 63% to 98% of traffic conflicts (van der Horst, 1984; Hyden, 1987; Garder, 1990; Hantula, 1994). Jerks, i.e. the sudden onset of severe deceleration should therefore provide a useful indication of traffic conflicts. It is expected that the number of jerks may diminish when ISA is switched on, due to reduced speed variation and general improved safety of driving. The algorithms for data processing to identify jerks braking are currently being developed but the approach to the planned analyses is briefly described below.

Figure 97 presents the speed profile of a series of braking events during a test run carried out in Leeds. Various magnitudes of speed drop are associated with different braking events. The aim of the planned analysis hence is to identify jerks from the vehicle speed database. The bottom half of Figure 97 illustrates the correspondent derivative of the vehicle speed (i.e. deceleration), which clearly highlights different patterns of normal braking and sudden and severe braking when vehicle speed is converted to deceleration.

However, caution should be taken when analysing braking behaviour based on unattended observation, such as the logged vehicle data collected in this project, to avoid misinterpretation of the data. It has been argued that braking patterns depend on individuals' driving style (Robertson et al, 1992; van der Horst et al, 1993). Consequently there is no clear threshold for identifying jerks from the vehicle acceleration profile across multiple drivers. For example, based on empirical data, Nygård (1999) reported that normal braking could lead to more deceleration than jerks caused by traffic conflicts. As shown in Table 37, the maximum deceleration derived from normal braking is more than the mean as well as the minimum values derived from traffic conflicts (i.e. in the form of absolute values). It is also worth noting that Nygård (1999) referred to serious traffic conflicts as drivers having to perform emergency braking to avoid a collision, which seamlessly corresponds to the jerky braking sought in the planned analysis.

Table 37: Deceleration rate in various traffic situations

Statistic	Normal traffic situation (N = 1400)	Serious traffic conflict (N = 5)
Maximum	−6.2	−7.2
Mean	−3.1	−6.1
Min	−2.1	−4.3

Note: 1. Unit: m/s^2
2. Source: Nygård (1999), p. 45.

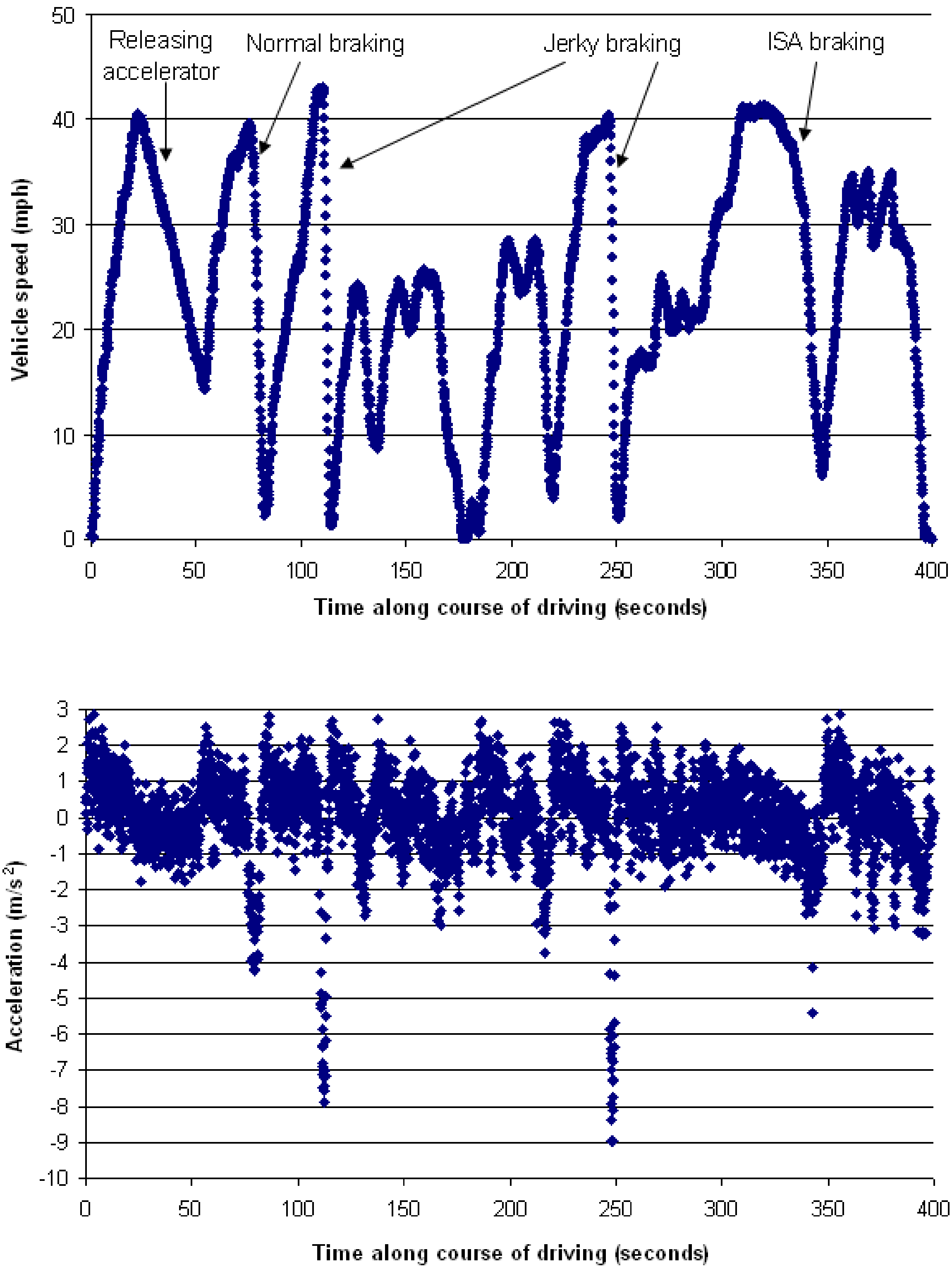


Figure 97: Speed profile of a series of braking events

By comparing the changes in deceleration (i.e. the derivative of deceleration), Nygård (1999) argued that a distinct difference could be identified between jerks above a certain threshold and normal braking, as depicted in Table 38. He further suggested that the difference of the derivative of deceleration between jerky braking and normal braking was higher than the differences among individual drivers' decelerations, which indicates that the derivative of deceleration is less driver dependent and hence is more reliable for identifying jerky braking than deceleration.

Table 38: Changes in deceleration in various traffic situations

Statistic	Normal traffic situation (N = 1400)	Serious traffic conflict (N = 5)
Maximum	−8.0	−14.7
Mean	−3.6	−12.4
Min	−2.2	−9.9

Note: 1. Unit: m/s^3
2. Source: Nygård (1999), p. 50.

Although Nygård (1999) made his arguments based on empirical evidence, the highly imbalanced samples (i.e. 5 against 1400) leads to concerns over the reliability of the proposed threshold (i.e. around −8.0 m/s^3) for distinguishing a severe jerk from normal braking.

Given that the vehicle speed database established in this project is enormous, a guide threshold however provides a useful reference for initial filtering of unwanted data. Once the likely jerks have been identified from the vehicle speed database, other techniques will be applied to confirm the braking patterns.

For example, Figure 98 illustrates the comparison between normal braking and a jerk by showing the speed profile, derivative of speed (i.e. deceleration), and derivative of deceleration (i.e. jerk) based on the data produced by the test run which took place in Leeds. It highlights *an abrupt and intense drop* at the beginning of a jerk.

The planned analysis of traffic conflicts will therefore be carried out based on a two-stage procedure. The developed algorithms will be used to identify possible traffic conflicts from the vehicle speed database by applying appropriate thresholds of deceleration and derivative of deceleration; the thresholds will be decided based on an extensive literature review. With the aid of visual inspection, the second stage will then further filter out 'fake' jerks.

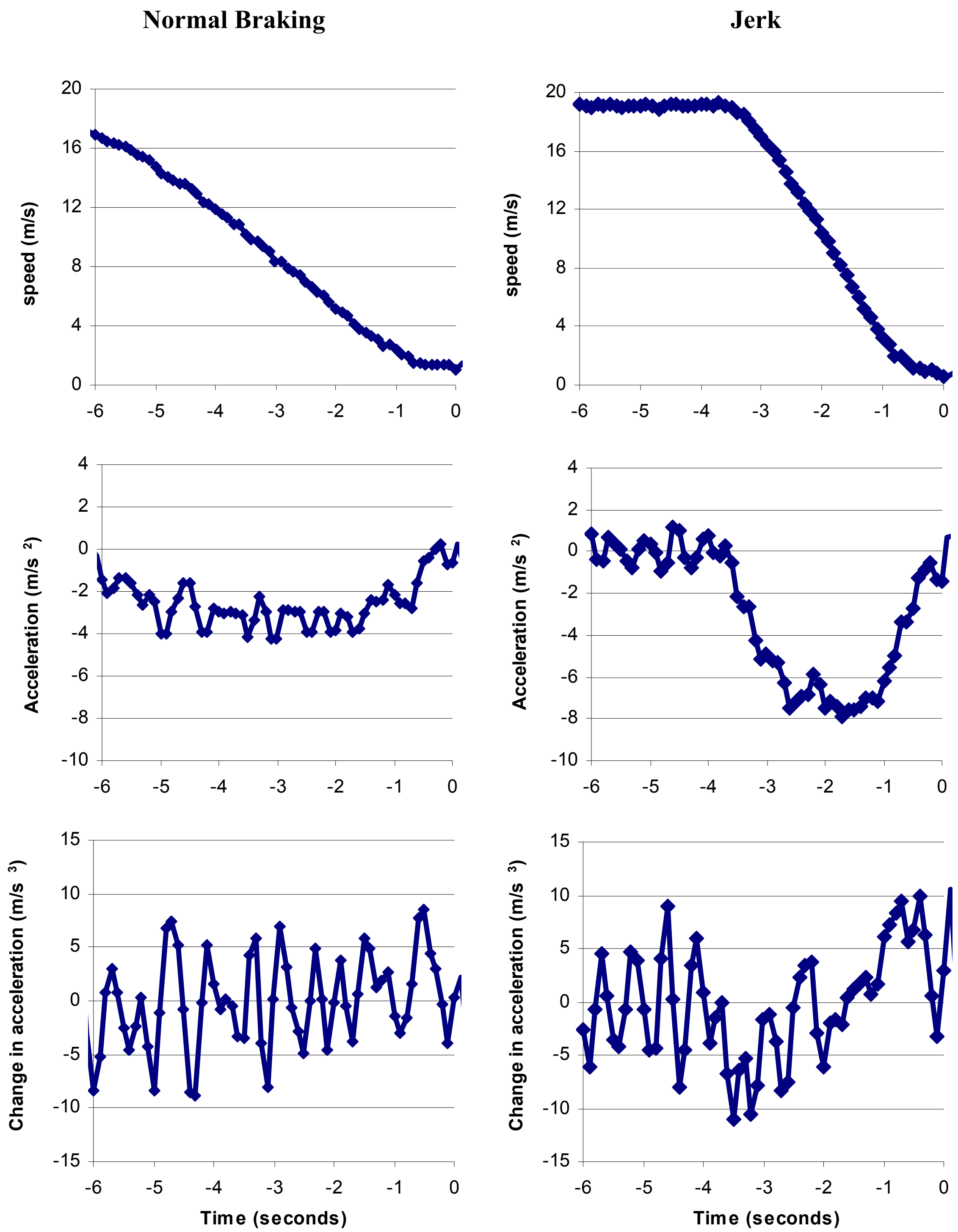


Figure 98: Comparison between a normal braking and a jerk

9. CONCLUSIONS AND IMPLICATIONS

9.1 Attitudinal changes

Usage of Intelligent Speed Adaptation had generally positive effects in terms of attitudes. Intention to speed on urban roads was reduced after the ISA was switched on, and the reduction persisted into Phase 3 when the ISA was once again disabled. Attitudes to speeding on urban roads became slightly more negative with ISA and this effect also persisted after the ISA was disabled. Attitudes to speeding on residential roads were even more negative, but were hardly affected by ISA and became slightly less negative when ISA was switched off. For urban and residential roads, but not for motorways, the system appears to have heightened drivers' awareness of the legal implications of speeding.

Rather unexpectedly, there was generally an increase in drivers' perceived behavioural control. This is slightly surprising, because it was anticipated that driving with the system would decrease drivers' perceptions of control, since the system was taking control over some aspects of speed choice.

Drivers' self-reported propensity to exceed the speed in the previous month decreased during Phase 2 (except for the motorway scenario where there was a slight increase). For the urban and residential scenarios, self-reported speeding in Phase 3 increased but was still lower than that reported at Phase 1, suggesting that the effects of ISA may have been sustained even with unsupported driving. For the motorway scenario, self-reported speeding remained the same.

Self-reported driving errors and violations both decreased with ISA and this effect persisted after the ISA was switched off. The acceptability rating of the ISA system in terms of usefulness and satisfaction both improved over time. Usefulness may represent a social utility construct, whereas satisfaction has more to with fulfilment of personal goals. In the EVSC project, users' satisfaction ratings tended to go down once they used the ISA-equipped car. But in this trial satisfaction steadily improved over time, going from slightly negative to quite positive. It is quite encouraging that satisfaction was as its highest level after the system had been withdrawn.

9.2 Behavioural changes

The ISA system was observed to have a distinctive effect in terms of the transformation of the speed distribution across all speed zones except the 60 mph zones. This means that speeds over the speed limit and in particular very high exceeding of the limit was curtailed. On the 60 mph roads, speeding behaviour was already rare in the pre period (the first month), so it is not surprising that there was little change with ISA. The lack of speeding in these roads is presumably due to traffic and road geometry conditions, and is in line with national data. When ISA was switched on, a large proportion of the speed distribution initially spread over the speed limit was shifted to around or below the speed limit. Analysis of various statistics related to speed (mean, 85th percentile, etc.) revealed a 'V' shape across trial phases, i.e. the statistic goes down from Phase 1 to Phase 2, then up from Phase 2 to Phase 3. This pattern is especially prominent with respect to high percentiles of the speed distribution, which are strong indicators of speeding behaviour. ISA has not only diminished excessive speeding, but also led to a reduction in speed variation with positive implications for a reduction in accident occurrence.

The use of an overridable ISA system also provides an opportunity to demonstrate potential resistance from the driving population against its implementation, based on true behaviour instead of opinion. ISA was overridden more often on urban roads with 20 and 30 mph zones where drivers are most likely to encounter conflicts with vulnerable road users such as pedestrians and cyclists than in the rest of speed zones. In terms of demographic groups, male drivers, young drivers, and drivers who intend to break speed limits overrode the system more often than their counterpart drivers. Thus there is some tendency for ISA to be overridden on roads where it is perhaps needed most and by those drivers who in safety terms stand to benefit most from using it. As with other safety systems (e.g. seatbelts), there is therefore a tendency for those who need it most to use it least. This suggests that there may be a role for incentives to keep ISA active and discouragement of overriding when ISA is deployed on a voluntary or fleet basis.

In spite these findings, ISA still had a positive impact on all groups, including young drivers, males and intenders to speed. In addition to improved speed limit compliance, ISA also contributes to diminished negative driving behaviour across demographic groups, as revealed by the observation drives. Presumably due to the constraint on breaking speed limits, travel time increased, which has led to a negative side effect of increased amber light violations. In addition, the results of the cluster trial shows that increased ISA penetration may facilitate vehicle headway stabilisation, which if realised generally should deliver positive benefits in terms of smoother operation and reduced accidents across the entire traffic network.

This trial has also revealed that participants seemed to have adapted their reference to chosen speed between trial phases. During Phase 1 and 3 when the ISA system was turned off, participants were observed to obey the speed limits with reference to speedometer reading. During Phase 2, participants were observed to rely on the ISA system (i.e. throttle cut-off) instead of the speedometer reading. This has implications because the design used here had the speedometer reading high but the ISA system using true speed, meaning that if drivers used the ISA system to regulate maximum speed that speed would be higher than when using the speedometer for the same purpose. The obvious solution is for the speedometer regulations to be changed so that they read accurately. In addition, the current design of the ISA system does not restrict vehicle speed to posted speed limits (i.e. the speed limits provided by the digital maps) to absolute precision. The throttle control permits vehicle speed to go somewhat over the speed limit, due to hysteresis in the ISA system response to driver throttle demand. If drivers relied on the system to keep them within the speed limit, they might actually be above the limit. This would need to be considered in setting standards for real-world ISA.

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APPENDIX A: PARTICIPANTS AGREEMENT

Agreement between the University of Leeds and Participants in the Trial of Intelligent Speed Adaptation for the ISA-UK Project

I, as a participant in the trial, agree with the following terms:

I understand that the University of Leeds is providing the following:

1. The use of an ISA car for six months. After the six months, the participant will have to return the car and the keys. The vehicle remains the property of Arval Key fleets (the lease company).

2. Road tax on the vehicle.

3. Comprehensive insurance **for the named driver**. No other person is allowed to drive the car. This insurance covers personal and **occasional** business use of the car (except where special arrangements have been made). It does not cover use of the car for hire.

4. A roadside recovery service (provided through the leasing company ARVAL Key Fleets).

5. A contact telephone numbers, so that participants, can notify us of any problems with the vehicle or the ISA equipment. **The number is: 0113 343 1771**

6. The cost of servicing of the car, if required.

The University of Leeds agrees to the following:

7. All data collected automatically will be stored without name and address information on the participants.

8. No reports will be issued containing information which allows participants in the trial to be identified.

9. Data will not be supplied by the University to any third parties outside the project in any way which links that data to any individual participant.

10. Participants will be protected from intrusion by the press and media to the best of our ability.

My specific commitments are as follows:

11. I am responsible for providing:
    (a) Petrol

(b) Basic day-to-day maintenance of the car, i.e. maintain tyre pressure, top up oil and windscreen fluid.

12. I will comply with the terms of the insurance policy.

13. I will unscrew the radio aerial when taking the car through a carwash.

14. I will ensure that occupants of the car do not smoke.

15. I am responsible for paying any parking charges, parking tickets, fixed penalty tickets that occur as a result of my actions.

16. I agree to take reasonable care of the vehicle and lock it whenever left unattended.

17. I agree not to tamper with any of the equipment installed in the car.

18. I will not install any additional electronic equipment in the car. This includes hands-free mobile phones.

19. I will not place any additional carpet or mats in the front foot well on the driver's side of the vehicle.

20. If the car accumulates enough miles to require a service, I will take it into the local Skoda dealer in Leeds. The dealer is **D.M. Keith Ltd**, Thwaite Gate, Hunslett Low Road, Leeds LS10 1DY (tel. 0113 277 1777). Their Service Manager is aware of the ISA trial.

21. I agree not to drive the car outside England, Scotland and Wales.

22. I will notify the University of any plans to take the car outside the Leeds metropolitan area for more than three days at a time.

23. I understand that I am responsible for any insurance excess that may be incurred while the car is in my care.

24. I agree to the collection of data from the car and I understand that this means that the University will be able to record vehicle location at all times.

25. While the ISA system is operational, I agree to keep the ISA system engaged to the fullest extent possible and I understand that the car may be withdrawn if I do not do so.

26. I will provide access to the car by members of the ISA team in order to reconfigure the car from non-ISA to ISA and vice versa, and in order to download data from the car. This access will be at the end of the first, fifth and sixth months of my use of the car and will take place at the University. The last occasion (at six months) will be the one on which I return the car to the possession of the University.

27. I agree to attend the one special event, involving all the trial participants.

28. I agree to participate in four accompanied drives, in which I will drive the car along a specified route with by two staff members of the University as passengers. Each drive will take approximately one and a half hours and will be arranged by the University for times and dates that are mutually convenient.

29. I agree to the indefinite use of the data supplied by myself and obtained from the car by the University, its partners in the project (MIRA Ltd and NAVTEQ Professional Services) and the project sponsor (The Department for Transport) with the proviso that this data will not be stored in any electronic database that contains my personal contact information such as name, address or phone number(s).

30. I will notify the University if the ISA features are not working properly.

31. I will notify the University of any changes in my personal circumstances such as change of address or change in phone number(s).

32. I will notify the University of any changes in the status of my driving licence such as the incurrence of fixed penalty points or driving convictions.

33. I will notify the University immediately if there is any accident involving the car, or if the car is damaged or stolen (this is to be done on the phone number listed on item 5).

34. I agree not to contact the press or the broadcast media concerning the ISA trial or my role in it and to refer any approaches by the press or broadcast media to the University.

35. I understand that the University reserves the right to terminate this agreement at any time.

Participant (name in capitals) ____

Participant (signed) _______________________________ Date _________________

Witness (signed) ________________________________ Date _________________

APPENDIX B: SPECIFICATION OF VEHICLE DATA

Summary Files

The summary file is sent as an SMS message at the end of each trip (ignition-off or key position 1). This summary data file contains 23 variables with 105 characters. The data is in a continuous ASCII format and no comma separator between variables.

Field Code	Variable	Unit/format	Length	Columns	Notes
SF1	Unique identifier	ISA	3	1-3	Include this in order to filter out Spam text messages
SF1.5	Summary File Version	0-9	1	4	Version Number
SF2	Vehicle ID	01-XX	2	5-6	
SF3	Trip number	00001-XXXXX	5	7-11	
SF4	Trial phase	0 = test 1= month 1 2 = months 2-5 3 = month 6	1	12	Status of the ISA link (present or absent)
SF5	Date	yymmdd	6	13-18	
SF6	Time trip commenced	hhmmss	6	19-24	24 hour clock UTC
SF7	Time trip ended	hhmmss	6	25-30	24 hour clock UTC
SF8	Trip origin (x)	E or W	1	31	East/West, pad with #
SF9	Trip origin co-ordinates (x)	GPS x coordinates (3.5 format)	9	32-40	Longitude, *pad with 0*
SF10	Trip origin (y)	N or S	1	41	North/South, pad with #
SF11	Trip origin co-ordinates (y)	GPS y coordinates (3.5 format)	9	42-50	Latitude, *pad with 0*
SF12	Trip destination (x)	E or W	1	51	East/West, pad with #
SF13	Trip destination co-ordinates (x)	GPS x coordinates (3.5 format)	9	52-60	Longitude, *pad with 0*
SF14	Trip destination (y)	N or S	1	61	North/South, pad with #
SF15	Trip destination co-ordinates (y)	GPS y coordinates (3.5 format)	9	62-70	Latitude, *pad with 0*
SF16	Trip length	Miles (4.2 format)	7	71-77	
SF17	Maximum forward speed	Mph (3.2 format)	6	78-83	
SF18	Fuel used	Gallons (2.2 format)	5	84-88	
SF19	% time of ISA used	% (3.1 format)	5	89-93	
SF20	Worst Failure	01-99	2	94-95	See the following table
SF21	No. of declared failures	01-99	2	96-97	
SF22	Available disk space	00001-99999 Mb	5	98-102	
SF23	End of message	END	3	103-105	

Error Codes

Code	Description of Problem and Conditions Causing Error
01	Potential ISA Display Error
02	Emergency Disable activation
03	Potential ISA Brake System Error
04	Potential Data Availability Error
05	Invalid GPS time
10	Potential Throttle Pedal Position sensor failure
11	Potential Throttle Pedal Position sensor failure
12	Potential Throttle Pedal Position sensor failure
13	Potential Data Availability Error
14	Emergency Disable activation
15	Potential Opt-out/in switch
16	Potential Failure of Vehicle Direction signal or Navteq sensor box.
17	Potential Fault in the Navteq sensor box.
20	Potential Speed Pick-up failure
21	Potential Navteq System Error
22	Potential ISA Brake System Error
31	Potential Data availability Error
32	Potential Data availability Error
33	Potential SMS message failure
61	No GPS satellites seen throughout journey
62	Potential Reverse Light signal failure
63	Hard Disk Write Error – Navteq computer
64	Hard Disk Read Error
65	Potential Engine Speed Pick-up failure
66	Potential Test Mode Error
67	Potential Fuel Used signal error
68	Potential Hard Disc Storage Error
99	No Errors

Vehicle Data File

This data are stored on the computer and downloaded at the end of each observation drive (month 1, 2, 5 and 6). On the server, the data are stored in an SQL database. For the vehicle data file, data is **not** comma separated. There will be one vehicle data file for each journey. The main data file is a continuous ASCII stream. The data file consists of main header (MHF) generates after ignition-on or key position 3, main data file (MDF) records at 10 Hz and main footer (MFF) generates after ignition-off or key position 1.

Main Header

Field Code	Variable	Unit/format	Rate	Length	Column	Notes
MHF1	*Data type*	*H*	-	*1*	*1*	*Denotes Header*
MHF 1.5	*Vehicle data file Version*	*0-9*	-	*1*	*2*	
MHF2	*Vehicle ID*	*01-XX*	-	*2*	*3-4*	
MHF3	*Trip number*	*00001-XXXXX*	-	*5*	*5-9*	
MHF4	*Trial phase*	*0 = test* *1= month 1* *2 = months 2-5* *3 = month 6*	-	*1*	*10*	*Status of the ISA link (present or absent)*
MHF5	*Date*	*Yymmdd*	-	*6*	*11-16*	
MHF6	*Time trip commenced*	*Hhmmss*	-	*6*	*17-22*	*24 hour clock UTC*
MHF7	*Trip origin (x)*	*E or W*	-	*1*	*23*	*East/West,* pad with #
MHF8	*Trip origin co-ords (x)*	*GPS x coordinates (3.5 format)*	-	*9*	*24-32*	*longitude, pad with 0*
MHF9	*Trip origin (y)*	*N or S*	-	*1*	*33*	*North/South,* pad with #
MHF10	*Trip origin co-ords (y)*	*GPS y coordinates (3.5 format)*	-	*9*	*34-42*	*Latitude, pad with 0*
MHF11	*Link ID*	*SDAL format*	-	*16*	*43-58*	*Pad with 0*
MHF12	*Distance along the link*	*0000000-9999999*	-	*7*	*59-65*	*In cm. Pad with 0*
MHF13	*Confidence*	*000-100*	-	*3*	*66-68*	*Perhaps only 3 or 4 point scale*

Main Data File

Field Code	Variable	Unit/format	Rate	Length	Column	Notes
MDF1	Data type	D	-	1	1	Denotes Data
MDF2	ISA mode	00-99	10 Hz	2	2-3	
MDF3	Time	HHmmsstt	10 Hz	8	4-11	
MDF4	Speed	Mph (3.2 format)	10 Hz	6	12-17	
MDF5	Vehicle direction	F = Forward R = Reverse I = no valid gear	10 Hz	1	18	Pad with #.
MDF6	Speed limit	Mph (3.2 format)	10 Hz	6	19-24	Notes: ambiguous = 999.00 initialising = 888.00 no speed limit = 777.00 off map = 000.00
MDF7	Position (x)	E or W	10 Hz	1	25	East/West, pad with #
MDF8	Position co-ordinates (x)	GPS x coordinates (3.5 format)	10 Hz	9	26-34	Longitude, pad with 0
MDF9	Position (y)	N or S	10 Hz	1	35	North/South, pad with #
MDF10	Position co-ordinates (y)	GPS y coordinates (3.5 format)	10 Hz	9	36-44	Latitude, pad with 0
MDF11	Link ID	SDAL format	10 Hz	16	45-60	Code format not known. Pad with 0
MDF11 .5	Logical Direction	+ left to right, - right to left	10 Hz	1	61	Pad with #
MDF12	Distance along the link	0000000-9999999	10 Hz	7	62-68	In cm. Pad with 0 if unknown
MDF13	Confidence	000-100	10 Hz	3	69-71	Perhaps only 3 or 4 point scale
MDF14	Headway front	Metres (3.2 format)	10 Hz	6	72-77	Pad with Xs if no sensor
MDF15	Headway back	Metres (3.2 format)	10 Hz	6	78-83	Pad with Xs if no sensor
MDF16	User throttle	% (3.1 format)	10 Hz	5	84-88	NB Scale 13-78
MDF17	Output throttle	% (3.1 format)	10 Hz	5	89-93	NB Scale 13-78
MDF18	Engine speed	rpm (three first figures)	10 Hz	4	94-97	
MDF19	Users Brake	1 = On, 0 = Off	10 Hz	1	98	Pad with ~
MDF20	ISA Brake	1 = On, 0 = Off	10 Hz	1	99	Pad with~
MDF21	Heading	Degrees, 0 padded	10Hz	3	100-102	Zero padded, values 0-359.

Main Footer

Field Code	Variable	Unit/format	Rate	Length	Column	Notes
MFF1	*Data type*	*F*	-	*1*	*1*	*Denotes Footer*
MFF2	*Date*	*Yymmdd*		*6*	*2-7*	
MFF3	*Trip length*	*Miles (4.2 format)*	-	*7*	*8-14*	
MFF4	*Time trip ended*	*Hhmmss*	-	*6*	*15-20*	*24 hour clock UTC*
MFF5	*Trip destination (x)*	*E or W*	-	*1*	*21*	*East/West,* pad with #
MFF6	*Trip destination co-ordinates (x)*	*GPS x coordinates (3.5 format)*	-	*9*	*22-30*	*Longitude, pad with 0*
MFF7	*Trip destination (y)*	*N or S*	-	*1*	*31*	*North/South,* pad with #
MFF8	*Trip destination co-ordinates (y)*	*GPS Y coordinates, (3.5 format)*	-	*9*	*32-40*	*Latitude, pad with 0*
MFF9	*Link ID*	*SDAL format*	-	*16*	*41-56*	*Pad with 0*
MFF10	*Distance along the link*	*0000000-9999999*	-	*7*	*57-63*	*Pad with 0*
MFF11	*Confidence*	*000-100*	-	*3*	*64-66*	*Perhaps only 3 or 4 point scale*
MFF12	*Fuel used*	*Gallons (2.2 format)*	-	*5*	*67-71*	
MFF13	*Map Database Version*	*Mnn.nnn.nnn.nnn*	-	*15*	*72-85*	*Source Navteq. Pad with #*
MFF14	*Navteq Error message KF12*	*40 character string*	-	*40*	*87-126*	*Source Navteq pad with # if no info.*

APPENDIX C: RELIABILITY OF THE ISA SYSTEM IN FIELD TRIAL 1

Vehicle ID	Total number of days		Operational Rate (%)
	When the vehicle was on road	When the vehicle was on road & ISA system was working	
2	188	52	27.7
3	216	181	83.8
4	154	83	53.9
5	146	70	47.9
6	188	188	100
7	153	153	100
8	201	201	100
9	157	152	96.8
10	211	211	100
11	204	165	80.9
12	167	167	100
13	228	190	83.3
14	219	219	100
15	177	177	100
16	154	74	48.1
17	177	177	100
18	168	168	100
19	187	186	99.5
20	225	186	82.7
21	174	174	100
22	150	113	75.3
Overall operational rate			**84.8**

APPENDIX D: ANOVA RESULTS FOR KEY STATISTICS OF THE SPEED DISTRIBUTION ACROSS TRIAL PHASES

Table D1: ANOVA results for mean speed by gender

Gender group	Speed zone	Mean			Repeated measures ANOVA					
		Phase 1	Phase 2	Phase 3	*F* statistic	significance	Effect size	Post-hoc t-tests	PH2	PH3
Male	20	18.9	19.2	21.5	F(2,12) = 2.80	0.101	0.318	PH1	×	*
								PH2		×
	30	27.2	27.0	28.4	F(2,16) = 16.59	< 0.0005**	0.675	PH1	×	**
								PH2		**
	40	35.2	34.9	36.0	F(2,16) = 2.67	0.100	0.250	PH1	×	×
								PH2		*
	50	46.9	45.9	46.7	F(2,16) = 0.23	0.797	0.028	PH1	×	×
								PH2		×
	60	44.6	46.8	45.5	F(2,16) = 4.17	0.035*	0.342	PH1	*	×
								PH2		×
	70	64.5	63.6	66.6	F(2,16) = 0.68	0.522	0.078	PH1	×	×
								PH2		×
Female	20	20.6	19.3	20.6	F(2,8) = 0.95	0.427	0.192	PH1	×	×
								PH2		×
	30	26.7	25.9	26.7	F(2,18) = 3.78	0.043*	0.296	PH1	×	×
								PH2		**
	40	33.0	32.6	33.2	F(2,18) = 0.80	0.467	0.081	PH1	×	×
								PH2		×
	50	45.1	43.8	44.5	F(2,16) = 0.97	0.399	0.109	PH1	×	×
								PH2		×
	60	41.6	44.3	42.7	F(2,18) = 3.29	0.061	0.268	PH1	*	×
								PH2		×
	70	56.2	58.8	58.1	F(2,18) = 0.58	0.572	0.060	PH1	×	×
								PH2		×

Note:
1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant

Table D2: ANOVA results for the 85th percentile of the speed distribution by gender

Gender group	Speed zone	Mean: Phase 1	Mean: Phase 2	Mean: Phase 3	Repeated measures ANOVA: *F* statistic	significance	Effect size	Post-hoc t-tests: PH1–PH2	PH1–PH3	PH2–PH3
Male	20	24.2	24.3	27.8	F(2,12) = 2.13	0.162	0.262	×	*	×
	30	35.6	34.0	36.8	F(2,16) = 16.90	< 0.0005**	0.679	*	*	**
	40	44.2	42.9	44.9	F(2,16) = 3.53	0.054	0.306	×	×	*
	50	57.0	54.2	57.0	F(2,16) = 0.64	0.539	0.074	×	×	×
	60	55.0	56.9	56.1	F(2,16) = 1.69	0.215	0.175	×	×	×
	70	76.3	73.8	78.3	F(2,16) = 1.12	0.352	0.122	×	×	×
Female	20	25.8	25.6	26.8	F(2,8) = 0.32	0.734	0.074	×	×	×
	30	34.3	32.1	34.5	F(2,18) = 13.46	< 0.0005**	0.599	**	×	**
	40	40.9	39.9	41.2	F(2,18) = 2.14	0.147	0.192	×	×	×
	50	51.4	50.0	51.6	F(2,16) = 1.19	0.328	0.130	×	×	×
	60	51.1	54.1	52.2	F(2,18) = 3.73	0.044*	0.293	*	×	
	70	67.1	68.5	68.2	F(2,18) = 0.18	0.835	0.020	×	×	×

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant

Table D3: ANOVA results for mean speed between age groups

Age group	Speed zone	Phase 1	Phase 2	Phase 3	Repeated measures ANOVA			Post-hoc t-tests		
					F statistic	significance	Effect size	PH1–PH2	PH1–PH3	PH2–PH3
Young	20	18.2	18.7	19.8	F(2,10) = 0.96	0.414	0.162	×	×	×
	30	26.9	26.2	27.2	F(2,16) = 5.46	0.016*	0.406	×	×	**
	40	33.9	33.1	33.7	F(2,16) = 1.43	0.269	0.152	×	×	×
	50	47.6	45.8	46.2	F(2,16) = 0.95	0.407	0.106	×	×	×
	60	43.8	45.7	43.8	F(2,16) = 2.18	0.145	0.214	×	×	×
	70	60.2	61.7	62.9	F(2,16) = 0.55	0.589	0.064	×	×	×
Old	20	21.0	19.7	22.5	F(2,10) = 2.41	0.140	0.325	×	×	*
	30	27.0	26.6	27.9	F(2,18) = 6.28	0.009**	0.411	×	×	**
	40	34.1	34.2	35.3	F(2,18) = 4.99	0.019*	0.357	×	×	*
	50	44.5	44.0	45.0	F(2,16) = 0.37	0.694	0.045	×	×	×
	60	42.3	45.3	44.2	F(2,18) = 7.40	0.005*	0.451	**	**	×
	70	60.1	60.5	61.5	F(2,18) = 0.14	0.869	0.016	×	×	×

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant

Table D4: ANOVA results for the 85th percentile of the speed distribution between age groups

Age group	Speed zone	Phase 1	Phase 2	Phase 3	Repeated measures ANOVA			Post-hoc t-tests		
					F statistic	significance	Effect size	PH1–PH2	PH1–PH3	PH2–PH3
Young	20	23.5	24.5	26.3	F(2,10) = 0.88	0.444	0.150	×	×	×
	30	35.3	33.2	35.5	F(2,16) = 14.26	$< 0.0005^{**}$	0.641	*	×	**
	40	42.6	40.9	42.0	F(2,16) = 2.88	0.086	0.265	*	×	×
	50	55.9	52.8	54.9	F(2,16) = 0.92	0.419	0.103	×	×	×
	60	54.2	55.4	53.6	F(2,16) = 1.49	0.255	0.157	×	×	×
	70	71.2	72.4	72.6	F(2,16) = 0.15	0.862	0.018	×	×	×
Old	20	26.3	25.2	28.5	F(2,10) = 1.97	0.190	0.282	×	×	×
	30	34.6	32.8	35.6	F(2,18) = 14.61	$< 0.0005^{**}$	0.619	**	×	**
	40	42.4	41.6	43.8	F(2,18) = 5.51	0.014^{*}	0.380	×	×	**
	50	52.6	51.4	53.6	F(2,16) = 0.64	0.542	0.074	×	×	×
	60	51.9	55.4	54.5	F(2,18) = 7.93	0.003^{**}	0.469	**	**	×
	70	71.7	69.7	73.3	F(2,18) = 0.96	0.402	0.096	×	×	×

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant

Table D5: ANOVA results for mean speed between intention groups

Intention group	Speed zone	Phase 1	Phase 2	Phase 3	Repeated measures ANOVA			Post-hoc t-tests		
					F statistic	significance	Effect size	PH1 vs PH2	PH1 vs PH3	PH2 vs PH3
Intender	20	20.0	20.0	21.4	F(2,6) = 0.80	0.432	0.113	×	×	×
	30	27.5	26.7	27.7	F(2,14) = 8.02	0.005**	0.534	*	×	**
	40	35.0	34.1	34.9	F(2,14) = 2.47	0.120	0.261	*	×	×
	50	47.3	44.6	44.9	F(2,14) = 2.54	0.115	0.266	×	×	×
	60	44.1	47.6	46.4	F(2,14) = 7.71	0.006**	0.524	*	**	×
	70	61.2	62.5	63.5	F(2,14) = 0.27	0.768	0.037	×	×	×
Non intender	20	18.8	17.5	20.7	F(2,14) = 3.80	0.086	0.559	×	×	*
	30	26.6	26.2	27.4	F(2,20) = 5.48	0.013*	0.354	×	×	**
	40	33.3	33.4	34.2	F(2,20) = 2.46	0.111	0.198	×	×	*
	50	45.0	45.1	46.1	F(2,18) = 0.76	0.484	0.077	×	×	×
	60	42.2	44.0	42.3	F(2,20) = 2.41	0.115	0.194	*	×	×
	70	59.4	60.0	61.2	F(2,20) = 0.32	0.727	0.031	×	×	×

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant

Table D6: ANOVA results for the 85th percentile of the speed distribution between intention groups

Intention group	Speed zone	Phase 1	Phase 2	Phase 3	Repeated measures ANOVA			Post-hoc t-tests		
					F statistic	significance	Effect size	PH1–PH2	PH1–PH3	PH2–PH3
Intender	20	25.2	26.5	27.5	F(2,6) = 0.90	0.430	0.114	×	×	×
	30	35.4	33.3	35.6	F(2,14) = 12.98	0.001**	0.650	**	×	**
	40	43.8	42.1	43.4	F(2,14) = 3.71	0.051	0.346	×	×	×
	50	56.3	52.9	53.7	F(2,14) = 1.36	0.288	0.163	×	×	×
	60	53.9	57.4	56.5	F(2,14) = 4.92	0.024*	0.413	*	*	×
	70	72.8	73.1	74.0	F(2,14) = 0.07	0.931	0.010	×	×	×
Non intender	20	24.3	21.5	27.3	F(2,14) =5.74	0.040*	0.657	×	×	×
	30	34.6	32.8	35.6	F(2,20) = 16.27	< 0.0005**	0.619	**	×	**
	40	41.5	40.7	42.7	F(2,20) = 3.76	0.041*	0.273	×	×	*
	50	52.6	51.4	54.8	F(2,18) = 1.36	0.282	0.131	×	×	×
	60	52.3	54.0	52.3	F(2,20) = 2.24	0.132	0.183	*	×	×
	70	70.4	69.4	72.3	F(2,20) = 0.69	0.512	0.065	×	×	×

Note: 1. * denotes the mean difference is significant at the 0.05 level
2. ** denotes the mean difference is significant at the 0.01 level
3. × denotes the mean difference is not significant

APPENDIX E: THE WIENER FAHRPROBE CODING FORMS

Trip Number: **Vehicle_ID:** **Driver_ID:** **Date and Time:**

Section	**Start**	**Finish**
1	Entry Jct University Rd/Clarendon Rd	Exit Jct Woodhouse Ln/St Marks Rd

JUNCTIONS			
	Lane choice for proceeding		**Behaviour at traffic lights**
	correct		drives against red
	in time		drives against amber
	at the last moment		does not start when it is green
	Incorrect		starts too early
	Use of the indicator		**Gap Acceptance**
	indicates in time		safe
	does not indicate		Unsafe
	does not indicate in time		with traffic
	indicates ambiguously		without traffic
	Checks the situation with respect to other road users		inappropriate speed
	Yes		Aggressive
	No		

LINK								
	Overtaking or lane change		**Speed**	**0**	**1**	**2**	**3**	**4**
	Correctly		Inappropriate					
	not correct		Inappropriate for road geometry					
	in spite of oncoming traffic		too fast near VRUs					
	Without sufficient vision		brakes abruptly					
	while forbidden		unsteady speed					
	Because of a stationary obstacle		**Distance to the road user ahead**					
	lane change in time		too close					
	Use of the indicator		**Checks the situation with respect to other road users**					
	indicates in time		Yes					
	does not indicate		No					
	does not indicate in time		**Behaviour when merging**					
	indicates ambiguously		safe					
	Lane use		Unsafe					
	inaccurate, weaving		with traffic					
	extremely on the right side of the lane		without traffic					
	extremely on the left side of the lane		inappropriate speed					
	cuts the curve		Aggressive					

Lane use						**Overtaking**	
Left Lane						Over Took	Overtaken By
Centre Lane							
Right Lane							
Following	**0**	**1**	**2**	**3**	**4**		
% Journey							
% Too Close							